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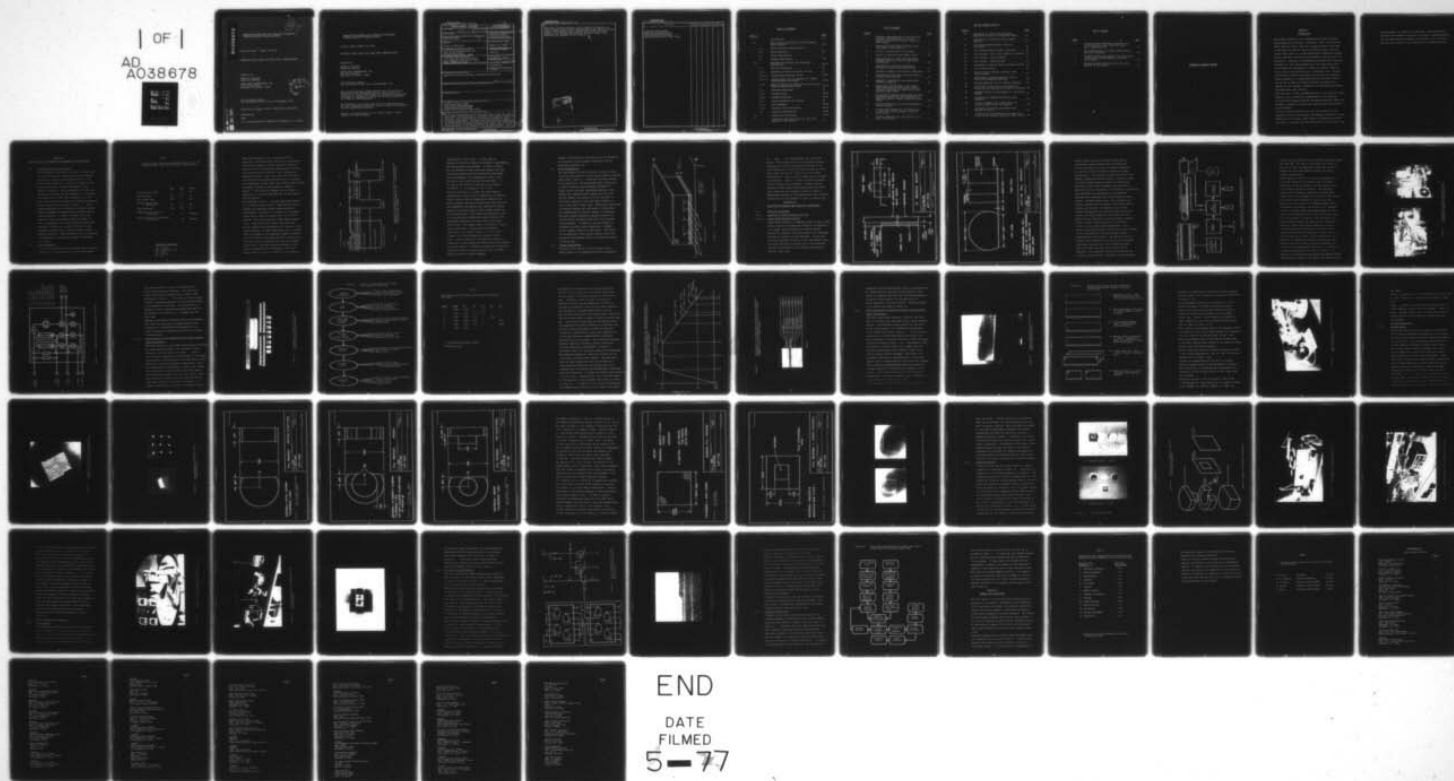
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MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING
PROGRAM QUARTERLY TECHNICAL REPORT

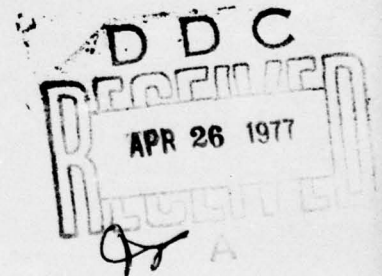
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INJECTION LASER DIODES FOR FIBER OPTIC COMMUNICATIONS

Prepared by:

Thomas E. Stockton
Operations Manager

LASER DIODE LABORATORIES, INC.
205 Forrest Street
Metuchen, New Jersey 08840



First Quarterly Report
for the Period 30 June 1976 to 30 September 1976

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The design and fabrication of injection laser diodes for use in fiber optic communications is discussed with regard to material synthesis, chip configuration, and device assembly in manufacturing environment. The opto-electronic source is based on the GaAs-GaAlAs double heterojunction structure and consists of a parallel array of lasers formed by the application of triple stripe geometry to the surface of the epitaxial wafer. The			

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monolithic triad of discrete lasing elements is mounted in a high frequency package which incorporates a high quality optical window. This report covers progress made during the first quarter of the program and outlines the major steps in the manufacturing sequence of the IL device.

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QUARTERLY TECHNICAL REPORT

SECTION I
INTRODUCTION

The primary objective of this Manufacturing Method and Technology Engineering Program is threefold. First, the Injection Laser Diode for use in Fiber Optic Communications as outlined in Specification SCS-516 must be transferred from a developmental device type to a volume manufactured commercial product without adversely affecting the performance characteristics of the device. Secondly, the manufacturing methods and techniques necessary for the volume production of the laser diode must be developed and implemented to insure the highest degree of device quality and reliability at a reasonable cost. Thirdly, verification of device performance and quality for injection lasers produced in a volume manufacturing environment must be carried out by means of rigorous testing and evaluation to demonstrate the technical adequacy of the manufacturing methods developed under this contract.

With this goal in mind, the MMTE program for the Injection Laser Diode for use in Fiber Optic Communications was organized utilizing the Program Evaluation and Review Technique (PERT) for planning, scheduling, controlling, and evaluating the progress of the program.

The major program objectives for the first quarter of the program include the procurement of components essential for the fabrication of prototype laser diodes, preliminary evaluation of epitaxial material, and the construction of life racks to be

used throughout the course of the program. The procurement of materials and equipment along with the status of process development of manufacturing techniques is discussed in the following sections with respect to the achievement of program milestones.

SECTION II

DEVICE DESIGN REQUIREMENTS AND PERFORMANCE SPECIFICATIONS

2.1 Electro-Optical Characteristics.

The performance characteristics of the Injection Laser for use in Fiber Optic Communications are described in detail in Technical Specification SCS-516. The device may be generally described as a double-hetero-junction (DH) GaAs - GaAlAs semiconductor laser capable of high data rate transmission at an emitting wavelength of 820 nm at room temperature. In addition, the device must be fiber optic compatible. An outline of the major electro-optical performance characteristics of the device is shown in Table 1. A more detailed description of the device, including environmental performance and parameter test methods can be found in SCS-516. In order to provide for a high degree of fiber optic system integrity through the use of redundancy, the injection laser diode has been designed to consist of a triad of discrete lasing elements contained within a single crystal of semiconductor material. This construction will be referred to as "monolithic triple stripe geometry" throughout this report.

2.2 Device Structure.

To achieve the electro-optical characteristics outlined in Table 1, the narrow cavity ($< .5\mu\text{m}$) GaAs-GaAlAs

Table 1

Electro-optical Performance Characteristics of the
Injection Laser Diode for Fiber Optic Communications.

	<u>Min.</u>	<u>Max.</u>	<u>Units</u>
Optical Stripe Width	-	25	μm
Stripe Spacing	120	130	μm
Peak Output Power	200	-	mW
Average Output Power per Stripe	6.3	7.0	mW
Peak Wavelength	800	830	nm
Beam Divergence Parallel to Junction	-	15	degrees
Beam Divergence Perpendicular to Junction	-	40	degrees

Operating Conditions

$I_p = 3\text{A max.}$
 $V_f = 2.0\text{V max. @ } 3\text{A.}$
 $T_a = 25^\circ\text{C}$
 $t_p = 10 \text{ nsec}$
 $DF = 10\%$

double heterojunction laser structure has been employed in conjunction with Laser Diode Laboratories' unique stripe geometry current isolation technique. Devices of this structure have demonstrated low threshold current density ($<1\text{KA}/\text{cm}^2$), high differential quantum efficiency ($>50\%$), fast rise time ($<200\text{ psec}$), and sufficiently good beam characteristics to satisfy the requirements of most fiber optic systems applications. A schematic diagram of the structure is shown in Figure 1 along with the bandgap, E_g , and index of refraction, n , profiles perpendicular to the plane of the P/N junction.

The substrate, region 1, is n-type GaAs doped with Si to 2×10^{18} , with EPD $<1\text{K}/\text{cm}^2$. Existing dislocation networks and substrate surface imperfections are terminated by the growth of at least one n-type GaAs buffer layer, region 2, doped with Te to 2×10^{18} . Regions 3 and 5 are n-type and p-type GaAlAs respectively. These two layers confine light generated by the injection and recombination of carriers in the active region 3, a p-type GaAlAs layer (Si, 1×10^{18}). Light is confined to the waveguide formed by regions 3 and 5 by virtue of the slight decrease in index of refraction at their boundaries with the lower bandgap active layer. The peak emission wavelength of the laser is controlled by the bandgap of the active region, which in turn is a function of the aluminum

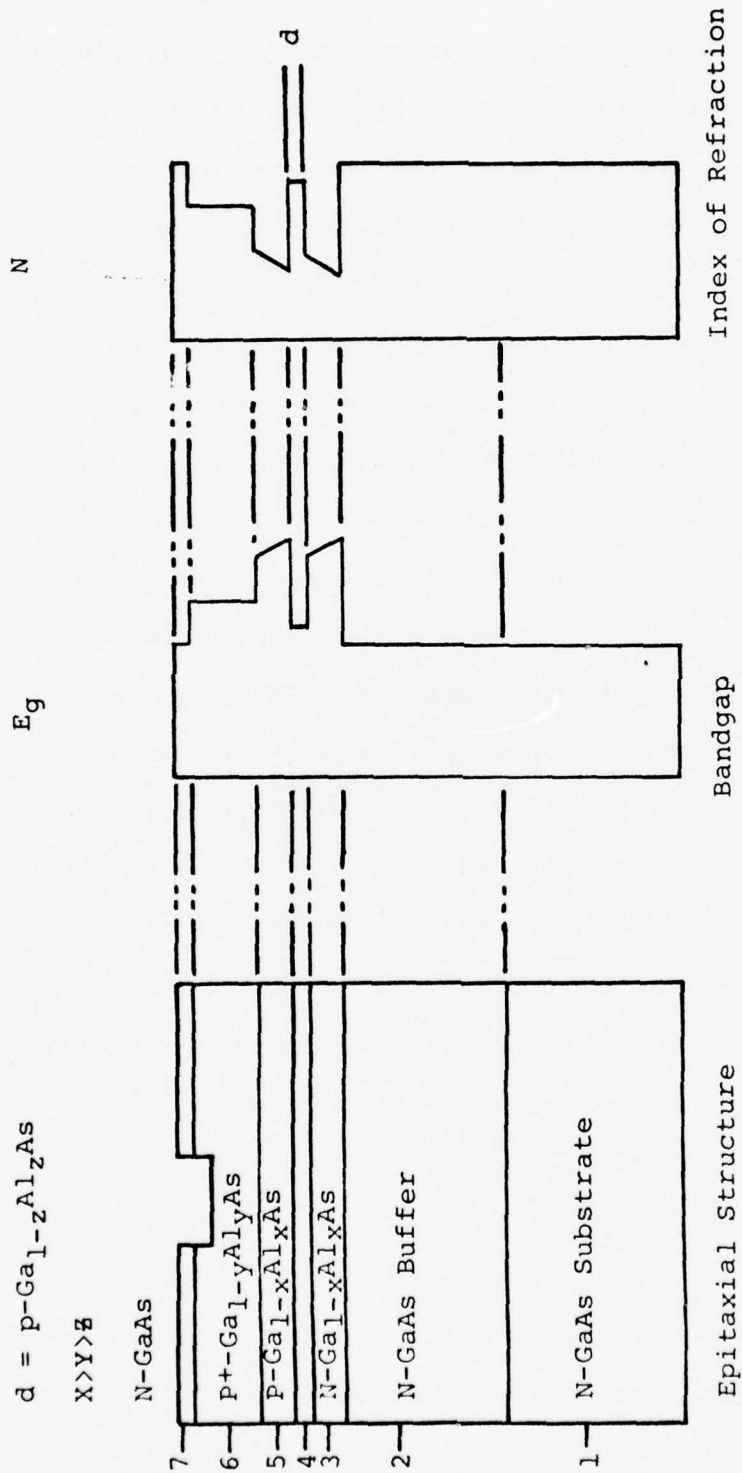


Figure 1 Schematic Representation of the Epitaxial Structure for Fabrication of Stripe Geometry Double Heterojunction Injection Laser Diodes.

concentration of this layer. In this case, 8% aluminum in the active region corresponds to approximately 820 nm peak emission wavelength. In order to obtain the low threshold current densities required for high duty cycle operation and for satisfactory high temperature performance, the recombination volume, hence the active region thickness must be kept small. In the case of CW injection lasers with J_{th} typically $< 1.5 \text{ KA/cm}^2$, 'd' is normally 0.3 to 0.4 μm .

Region 6 functions as a contact cap with aluminum incorporated in this p-type Ge doped layer to minimize lateral current flow by increasing its resistivity. Stripe geometry fabrication permits high duty cycle and room temperature CW operation by limiting the lasing region of the active layer to only a small portion of the junction width. This allows heat generated in the 25 μm lasing region beneath the contact stripe to be dissipated throughout the entire bulk of the laser diode pellet. The topmost region 7 consists of lightly doped n-type GaAs. Following photolithographic definition of the contact stripe, 15 to 20 μm wide channels are etched through this current blocking layer. Under conditions of forward bias, current is restricted to flow through the active region only beneath the etched channel. Elsewhere, because the p/n junction formed by interface between regions 6 and 7 is back-biased, the cavity remains unpumped.

Details of the epitaxial synthesis and wafer processing for monolithic stripe geometry fabrication will be discussed in Section III.

2.3 Array Configuration.

The requirements of SCS-516 dictate the array configuration for the monolithic triple stripe geometry injection laser diode. Figure 2 illustrates the main features of the diode chip. The diode essentially consists of a triad of discrete lasing elements embedded in a single chip of epitaxial GaAs-GaAlAs material. Each element has a maximum optical source size of 25 μm and the elements are spaced at 125 μm intervals to facilitate coupling of each individual element to a triple fiber optic ribbon cable. Monolithic construction is preferred because the high degree of dimensional and compositional uniformity inherent in the hetero-epitaxial process guarantees optimum uniformity of electro-optical parameters among the three discrete lasing elements. In addition, the high degree of uniformity provides perfect geometrical alignment of the elements relative to each other. Fabrication of the monolithic triple stripe geometry array from epitaxially synthesized wafers is discussed in detail in Section III.

2.4 Package Requirements.

During the first quarter of the program, several modifications to the package outline were requested

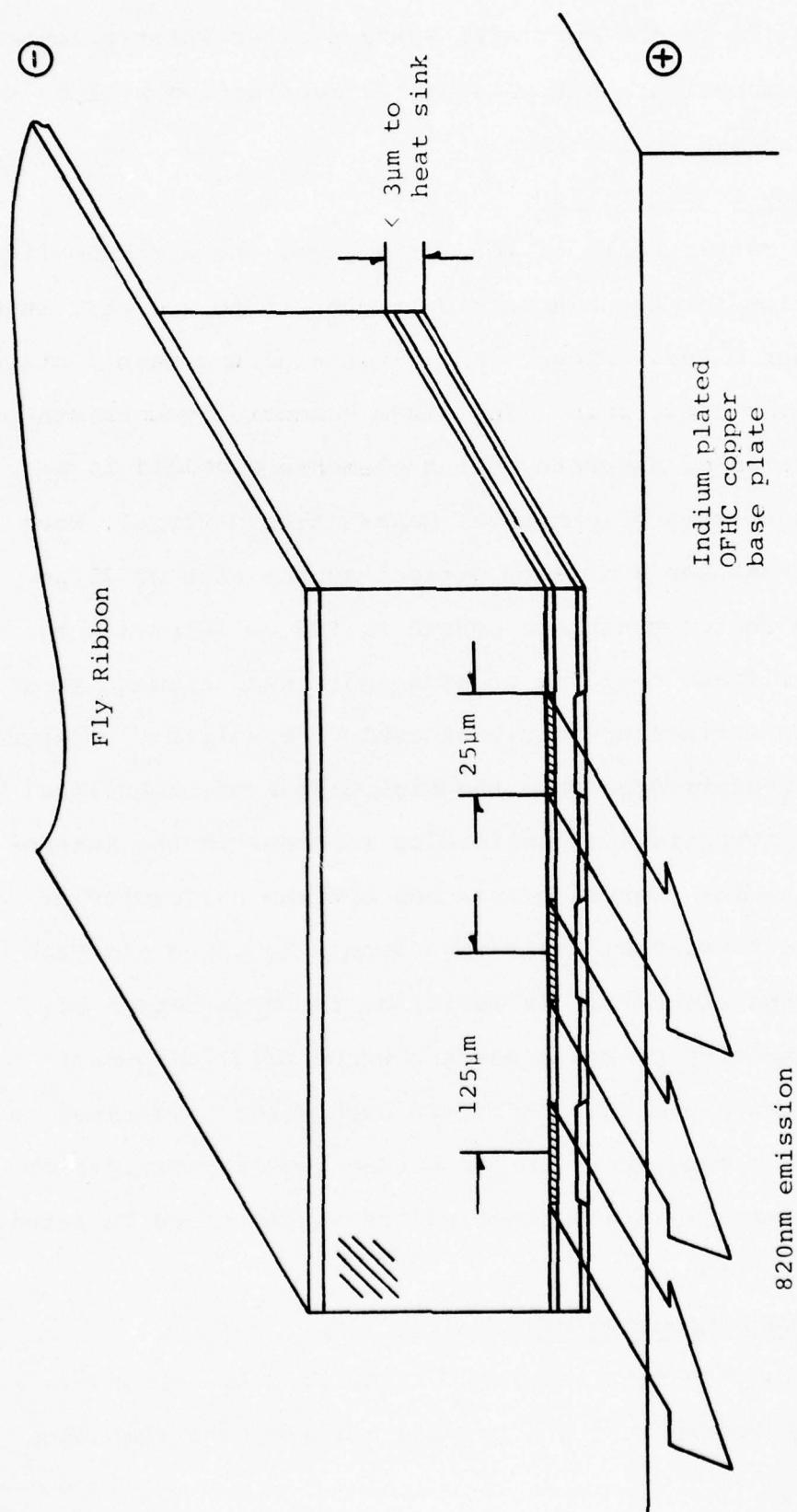


Figure 2 Monolithic Triple Stripe Geometry Laser Diode Module Configuration

by ECOM for incorporation into the device design. These modifications to the proposed package configuration involved increasing the height of the pill package base to better facilitate coupling to the fiber cable end ferrule. Also, the overall height was adjusted to allow the use of square optical windows in production. Figure 3 shows the modified package outline drawing with tolerances. A detail drawing showing the laser module mounting position and orientation within the pill package is given in Figure 4. Engineering drawings of the package parts and a detailed description of their assembly is given in Section III.

SECTION III

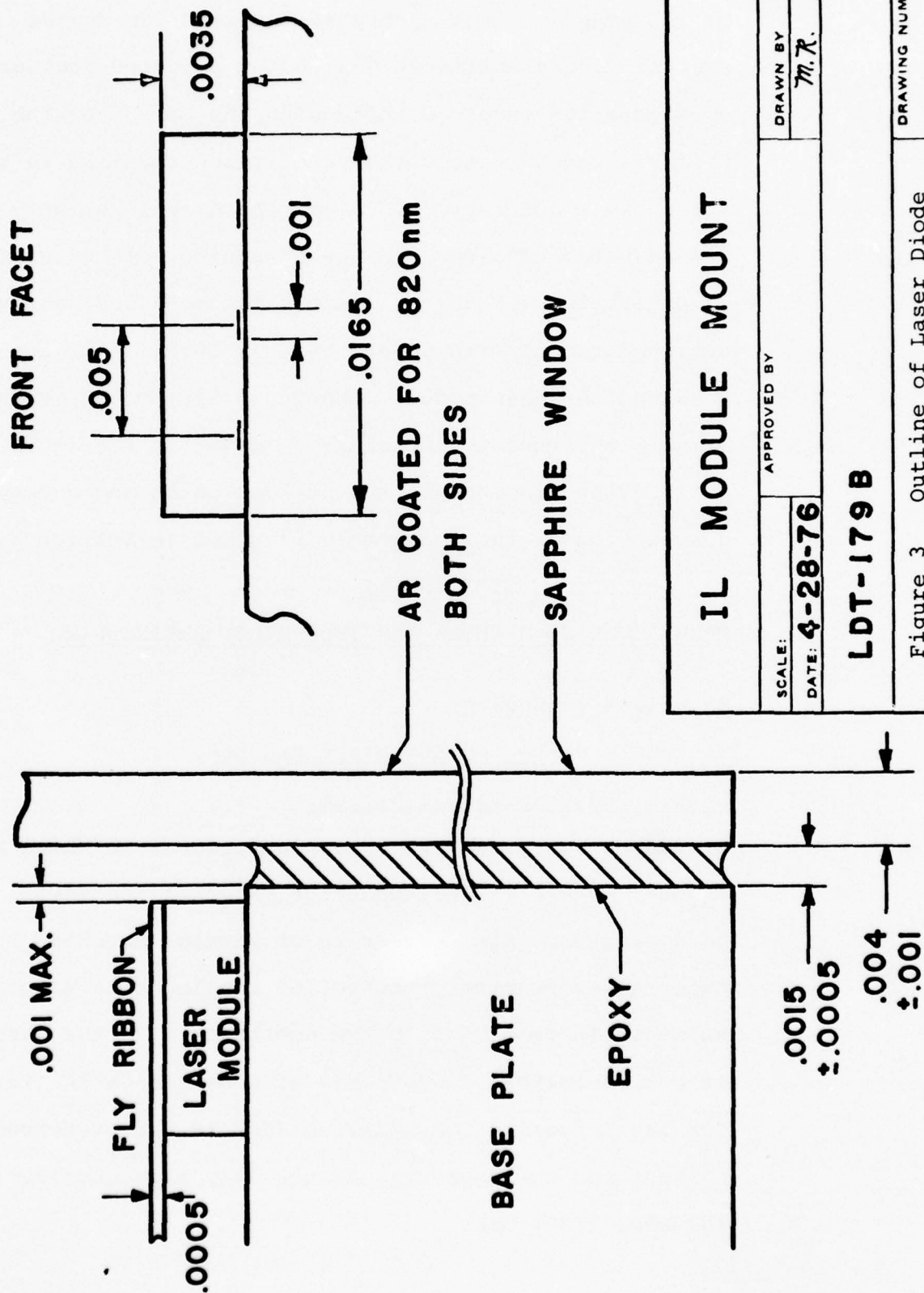
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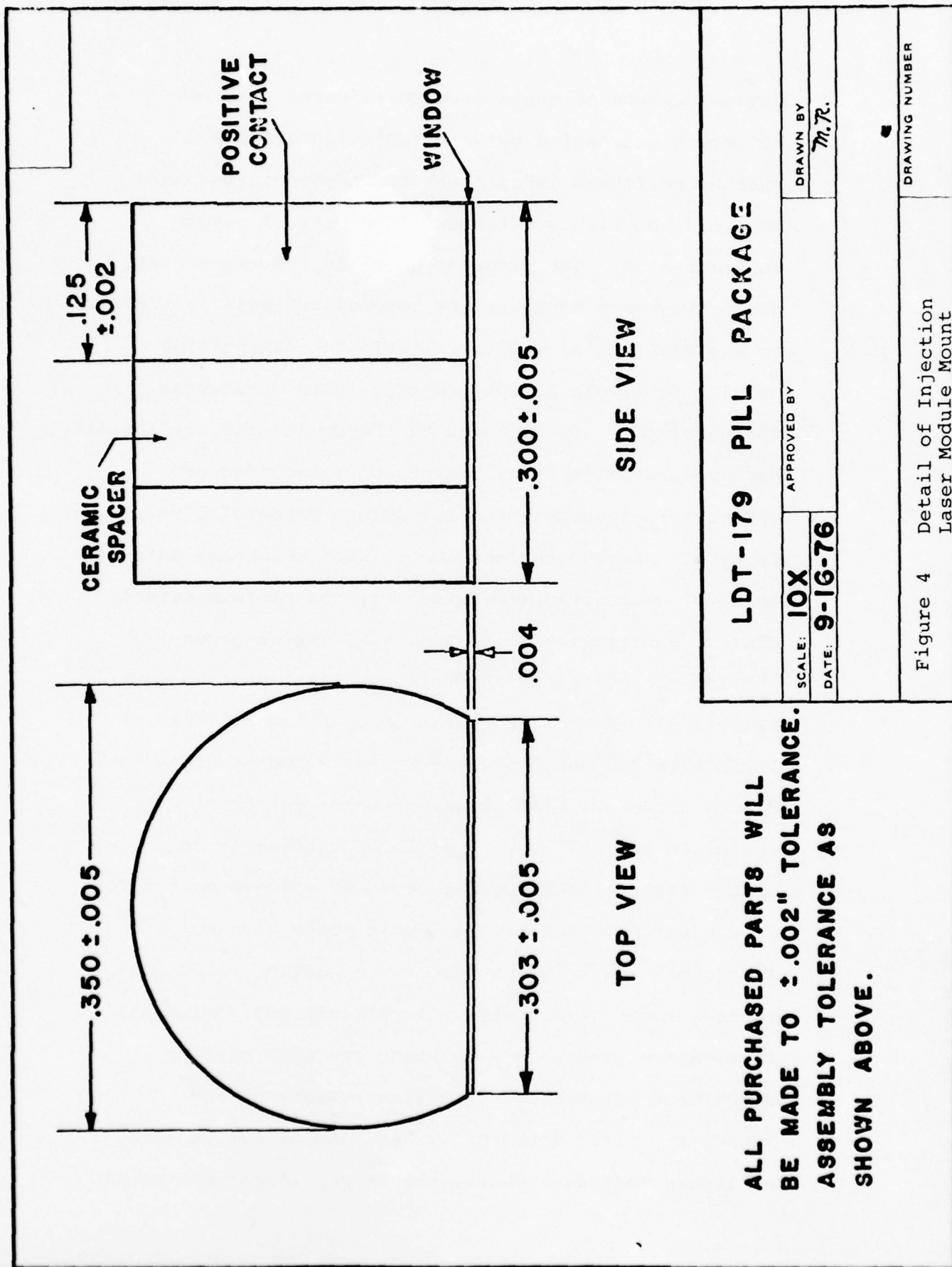
3.1 Materials Technology.

3.1.1 Synthesis of Device Structure via LPE.

3.1.1.1 Liquid Phase Epitaxial System.

Liquid phase epitaxy is a complex process in which single crystal layers of semiconductor material are deposited on a single crystal substrate of lattice matched material by precisely controlled cooling of a saturated solution in contact with the substrate. In the case of hetero-epitaxial synthesis of GaAs and GaAlAs layers for laser fabrication, gallium (Ga) is the preferred solvent and the substrate is normally high quality, low EPD, (100) GaAs.





Crystal growth of these structures takes place at temperatures ranging between 750°C and 900°C and must be performed in an inert or reducing atmosphere to avoid the highly detrimental effects of oxygen contamination. The properly designed LPE reactor and support systems must satisfy several criteria in order to yield epitaxial wafers suitable for fabricating monolithic triple stripe geometry laser structures. These criteria are dictated by the uniformity, reliability, and produceability requirements of semiconductor optoelectronic components for volume commercial manufacture. Maximum surface area, layer thickness uniformity, compositional uniformity, and minimum defect density are required. In addition, the as-grown surface morphology of the terminal layer must be compatible with photolithographic processing for the definition and patterning of stripe geometry contacts. Figure 5 shows a block diagram of the epitaxial system in use at Laser Diode Laboratories. This system incorporates several features which have resulted in the optimization of the liquid phase process:

Isothermal Heat Pipe Furnace - The sodium filled isothermal liner eliminates all vertical and horizontal temperature gradients and, hence provides uniform deposition rates over the entire surface of the substrate. The isothermal liner also allows the use of larger epitaxial boats, therefore, larger epitaxial

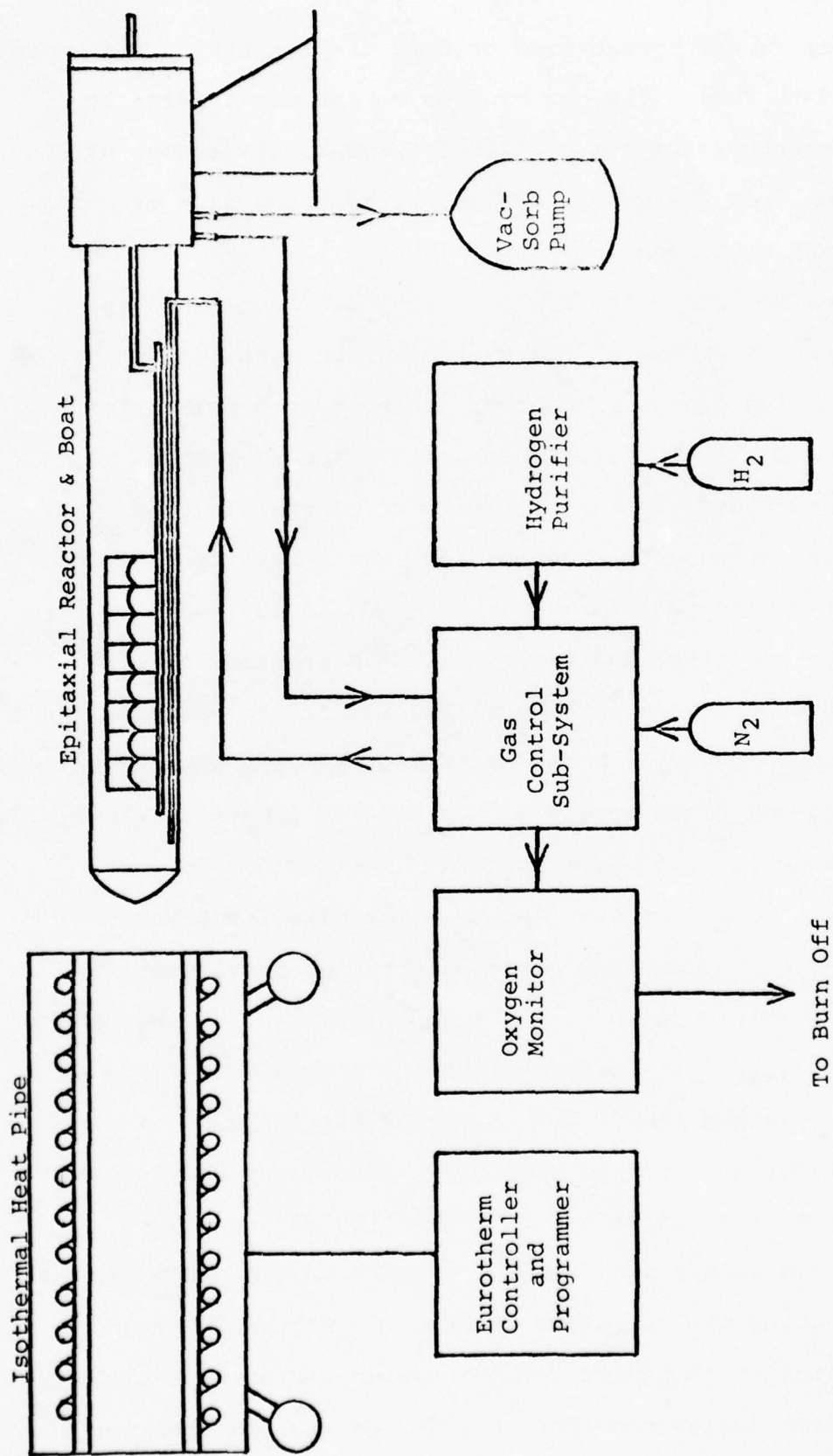


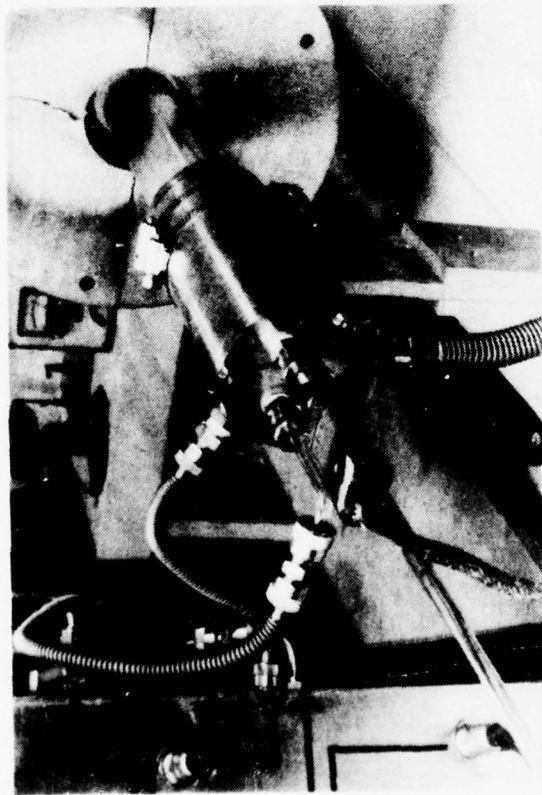
Figure 5 Block Diagram of Liquid Phase Epitaxial Systems Currently in Use at Laser Diode Laboratories.

wafers can be synthesized or more complex structures grown.

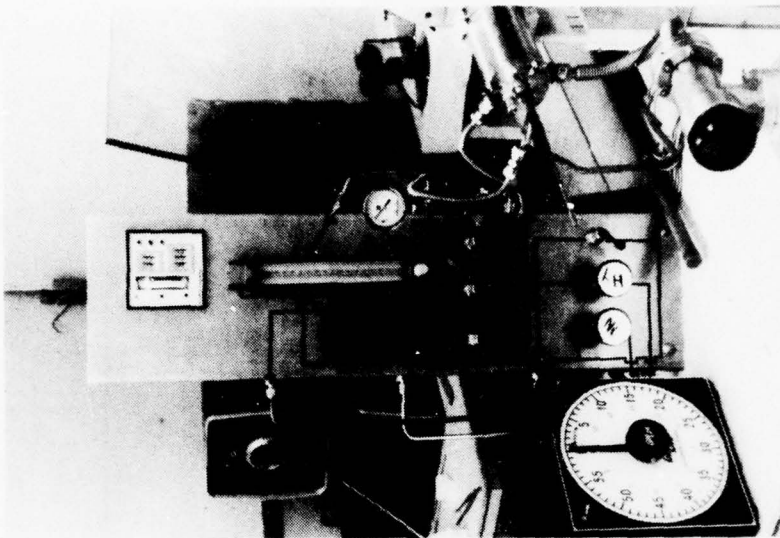
Vac Sorb Pump - The use of a molecular sieve prior to the start of the run completely removes all traces of oxygen from the growth ambient without the risk of organic contamination.

Oxygen Monitor - The use of a fuel cell apparatus in the output stream of the system allows continuous monitoring of the O_2 content of the system both prior to and during epitaxial synthesis. The apparatus assures system integrity resulting in reproducible growth rates, alloy composition, and defect free growth by preventing the formation of Al_2O_3 in the melt.

During the first quarter of the MMTE program, several improvements were made in the design of the epitaxial reactor. Notable among these improvements were the design and construction of new end cap apparatus shown in the photograph of Figure 6a. The new design can support higher vacuum, and operates with lower background O_2 levels than could be obtained previously. The optimized design now permits evacuation of the growth tube down to 80 microns and a steady state O_2 concentration of 0.1 ppm in the H_2 carrier gas. In addition, an improved gas supply sub-system has been designed for easier use by production personnel and is shown in the photograph of Figure 6b. A schematic indicating its operation is shown in Figure 7. In addition to obtaining optimum system performance through improved design concepts, the design and construction of



a.



b.

Figure 6 Photograph of Liquid Phase Epitaxial Reactors at Laser Diode Laboratories.

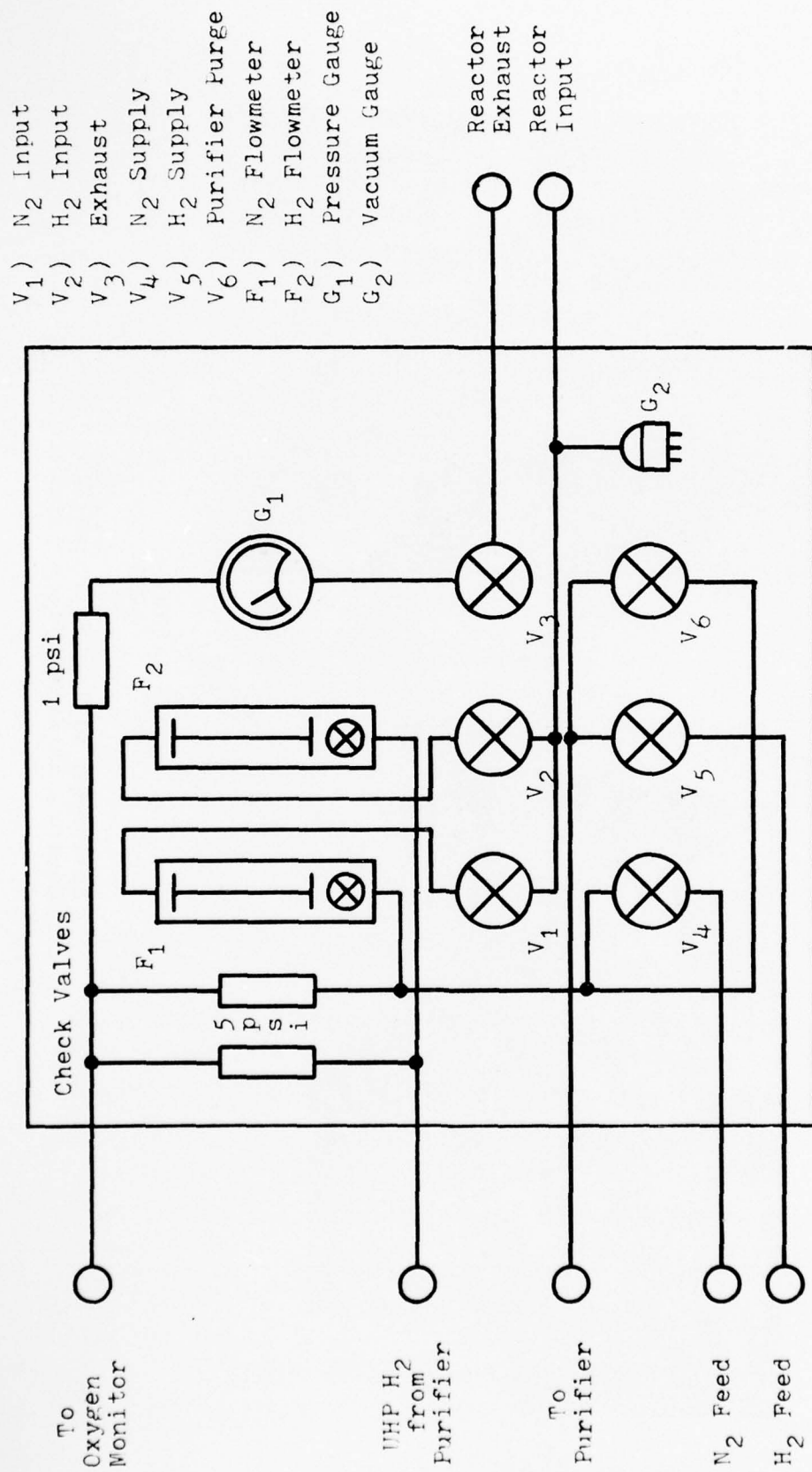


Figure 7 Schematic Diagram of Gas Control Subsystem

the epitaxial boat is crucial to obtaining high quality hetero-epitaxial material. The ultra high purity, high density graphite boat is shown in the photograph of Figure 8. The eight bin boat utilizes a built-in indexing mechanism for accurate positioning of the substrate in each bin. Also an extra bin is employed to remove excess gallium which may adhere to the surface of the wafer as it is removed from the final melt.

Together, the modified epitaxial reactor and epitaxial boat allow the generation of double heterojunction structures in a manufacturing environment for the volume production of monolithic triple stripe geometry injection lasers.

3.1.1.2 Growth Process for the Synthesis of the Double Heterojunction Structure.

Epitaxial synthesis of the double heterojunction structure is accomplished according to the sequence of events outlined in the flow chart of Figure 9. Table 2 lists the melt compositions for the growth of the double heterojunction structure used in the fabrication of the monolithic triple stripe geometry laser diode. After the appropriate melt ingredients, gallium (Ga) charges, and polycrystalline source wafers, have been loaded into consecutive growth bins, the single crystal (100) GaAs substrate is placed into the slider well of the high purity graphite boat (refer to Figure 8). A graphite cover plate is employed to eliminate surface

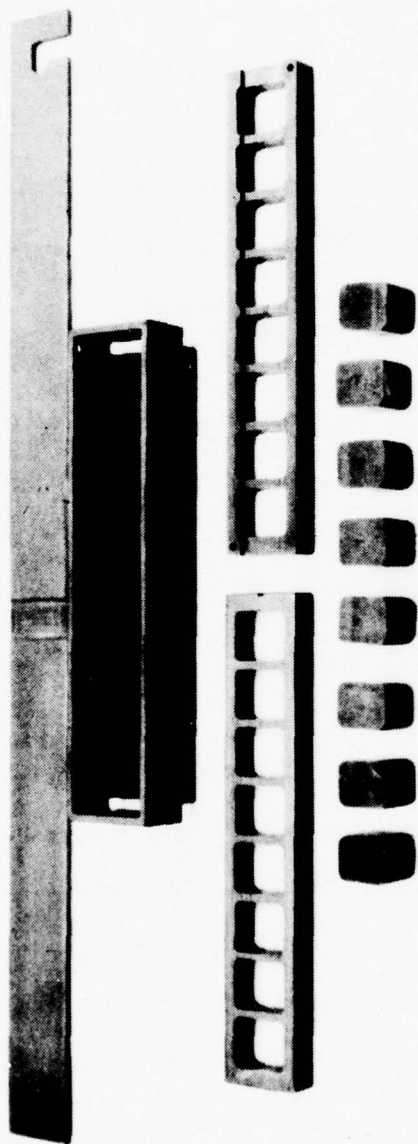


Figure 8 Photograph of Eight Bin Ultra High
Purity Graphite Epitaxial Boat.

Figure 9

Sequence of Operations for Liquid
Phase Epitaxial Synthesis.

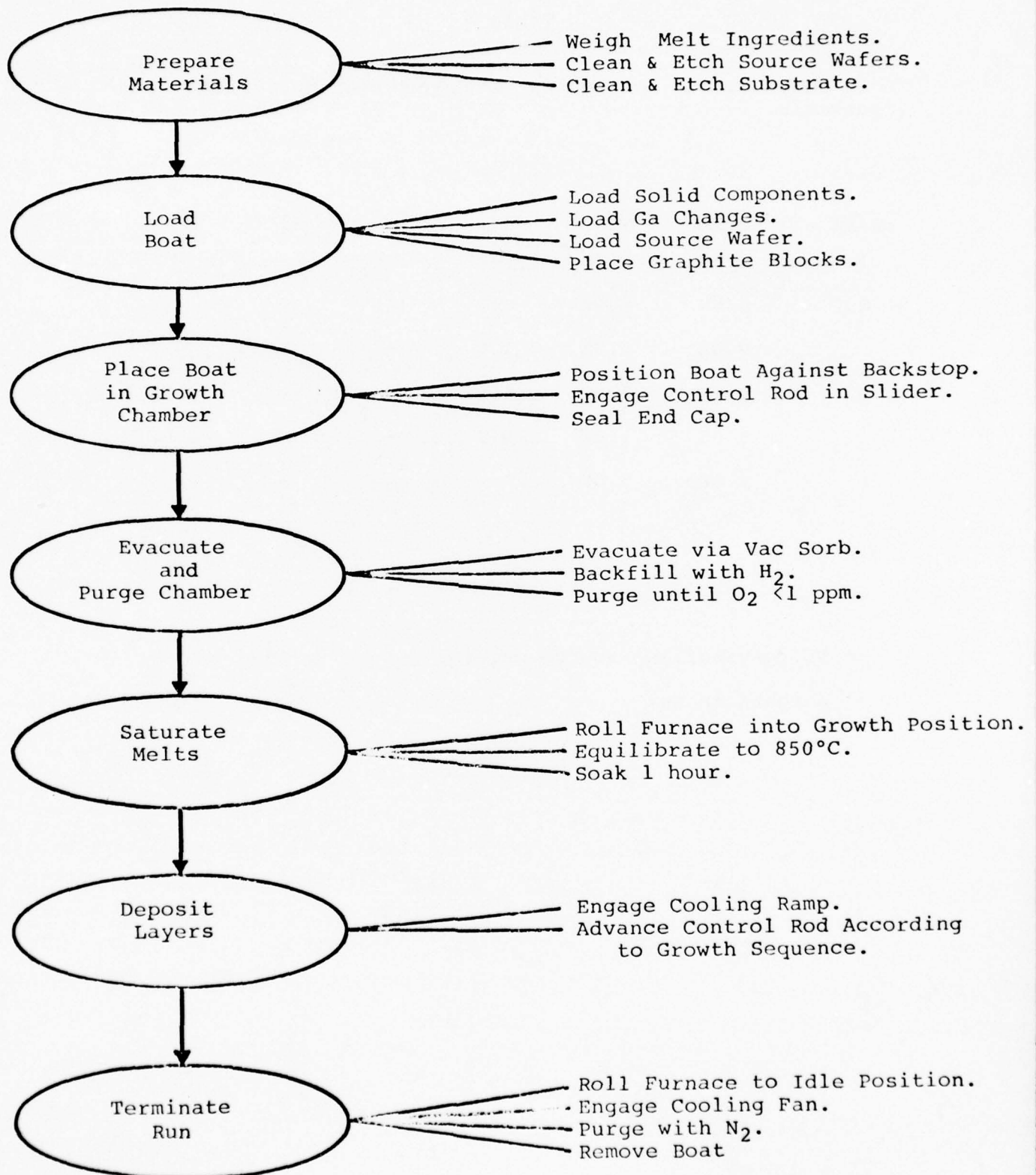


Table 2

Melt Compositions for Double Heterojunction Epitaxial Synthesis.

<u>Layer</u>	<u>*GaAs</u>	<u>Ga</u>	<u>Al</u>	<u>Te</u>	<u>Si</u>	<u>Ge</u>
1	0.6K	5.0K	-	1.0	-	-
2	0.6K	5.0K	6.0	1.0	-	-
3	0.6K	5.0K	1.0	-	15.0	-
4	0.6K	5.0K	6.0	-	-	0.1K
5	0.6K	5.0K	0.2	-	-	0.5K
6	0.6K	5.0K	-	-	-	-

* Polycrystalline source wafers.

** Weights in mg.

dissociation of the substrate during equilibration. The boat is then loaded into the quartz growth tube and the system is evacuated by means of the Vac-Sorb pump. Following a short H_2 purge, the system is brought up to the starting temperature of $850^\circ C$ by rolling the isothermal liner into the growth position. Melt saturation is accomplished during a one hour soak at $850^\circ C$ during which time enough GaAs is dissolved from the source wafers in order to exactly saturate each melt. This recently developed self-saturation scheme has simplified the growth procedure by eliminating the need for careful preweighing of GaAs for each melt. In addition, higher quality layers and increased run to run layer thickness reproducibility have been achieved with this technique. Once saturation has been achieved, epitaxial synthesis proceeds according to the time temperature program shown in Figure 10. Individual layers are epitaxially deposited by advancing the substrate through the consecutive growth bins for a precisely controlled time interval. Because growth rates for the various melts are well defined for a fixed starting temperature and cooling rate, layer thickness can be accurately and reproducibly controlled using this technique. A cleaved and etched cross section of a typical wafer synthesized for use in the fabrication of the monolithic triple geometry laser diodes is shown in Figure 11. In addition to the excellent dimensional and compositional uniformity of the layers, the surface

Figure 10

Temperature program used in the liquid phase epitaxial growth of double heterojunction structures for monolithic stripe geometry laser diodes.

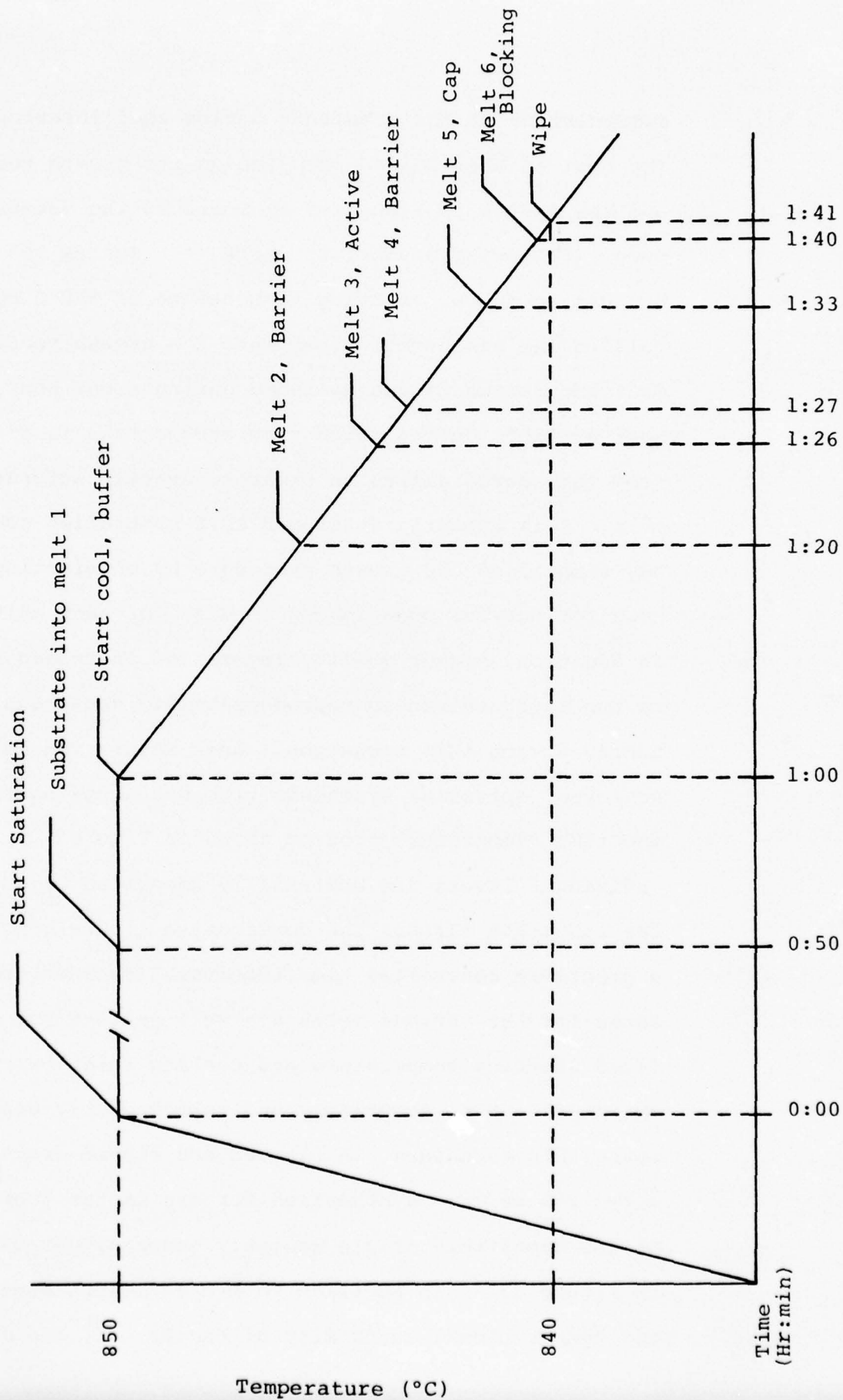
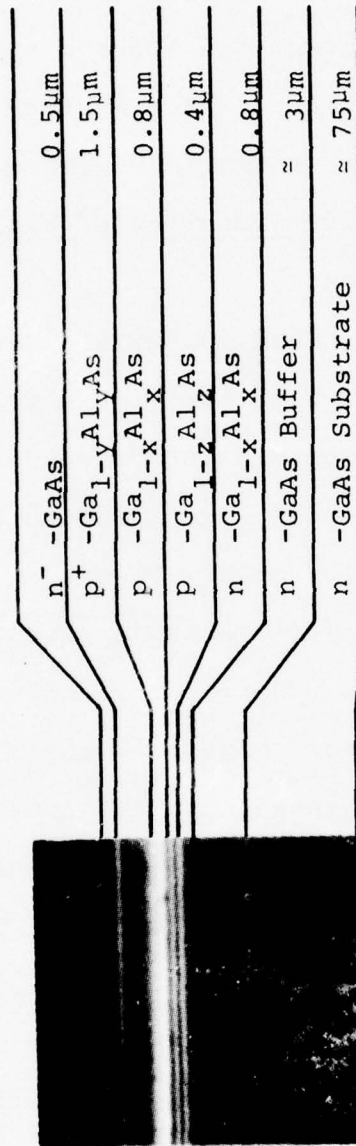


Figure 11

Photograph of typical double heterojunction structure required for the manufacture of monolithic stripe geometry injection laser diodes.



X>Y>B

morphology of the heteroepitaxial wafer is characterized by freedom from pit type defects and exhibits a high degree of flatness compatible with the photolithographic processing steps required for the application of stripe geometry to the wafer surface. Photomicrographs of the surface are shown in Figure 12.

3.1.2 Wafer Processing for Monolithic Triple Stripe Geometry Module Fabrication.

Following liquid phase epitaxial synthesis, the wafer must be processed into individual triple stripe geometry modules. The processing steps required for the fabrication of the modules, are illustrated schematically in the process flow chart, Figure 13. After epitaxial synthesis of the multiheterojunction structure, the wafer undergoes a preprocess cleaning to remove residual Ga from the surface, Figure 13 (a). Approximately .050" of material is cleaved from all four edges creating mutually perpendicular $\langle 110 \rangle$ reference planes to be used for channel stripe alignment. The proper $\langle 110 \rangle$ alignment plane must be identified prior to epitaxial growth since a V-shaped channel cross section is desired. This is normally accomplished by defining channels on a sample substrate and observing the channels' cross section. Once identification of the $\langle \bar{1}10 \rangle$ has been accomplished, the proper alignment plane is known for all substrates cut from a given ingot.

Photolithographic definition of the stripe contact

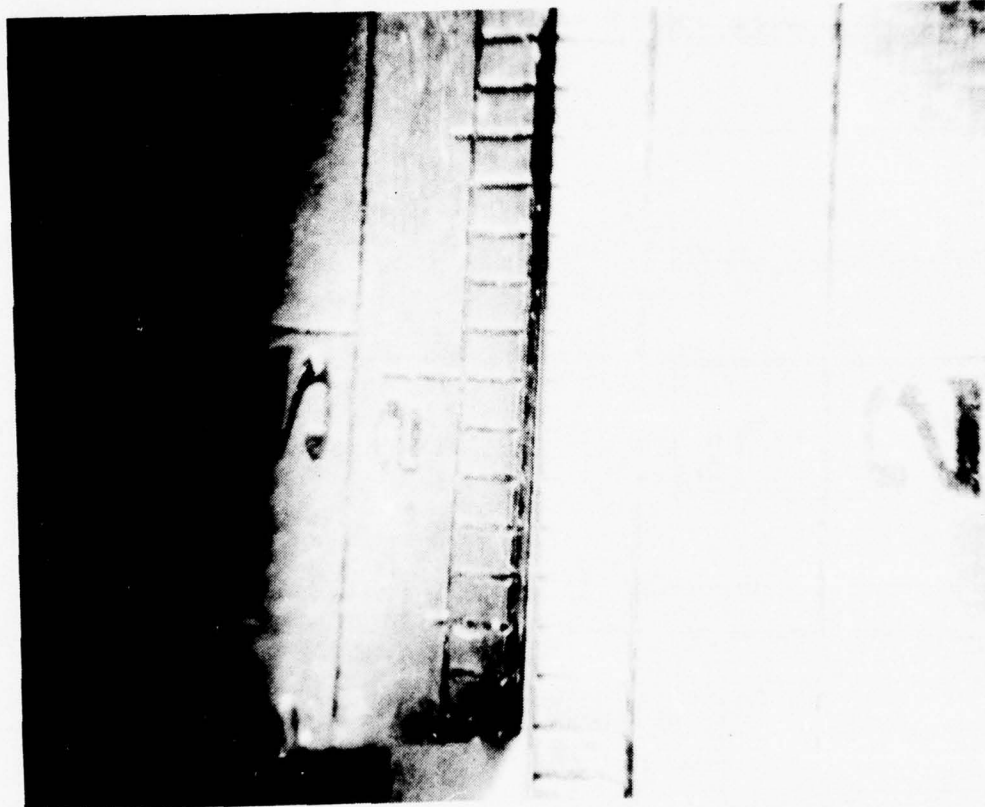
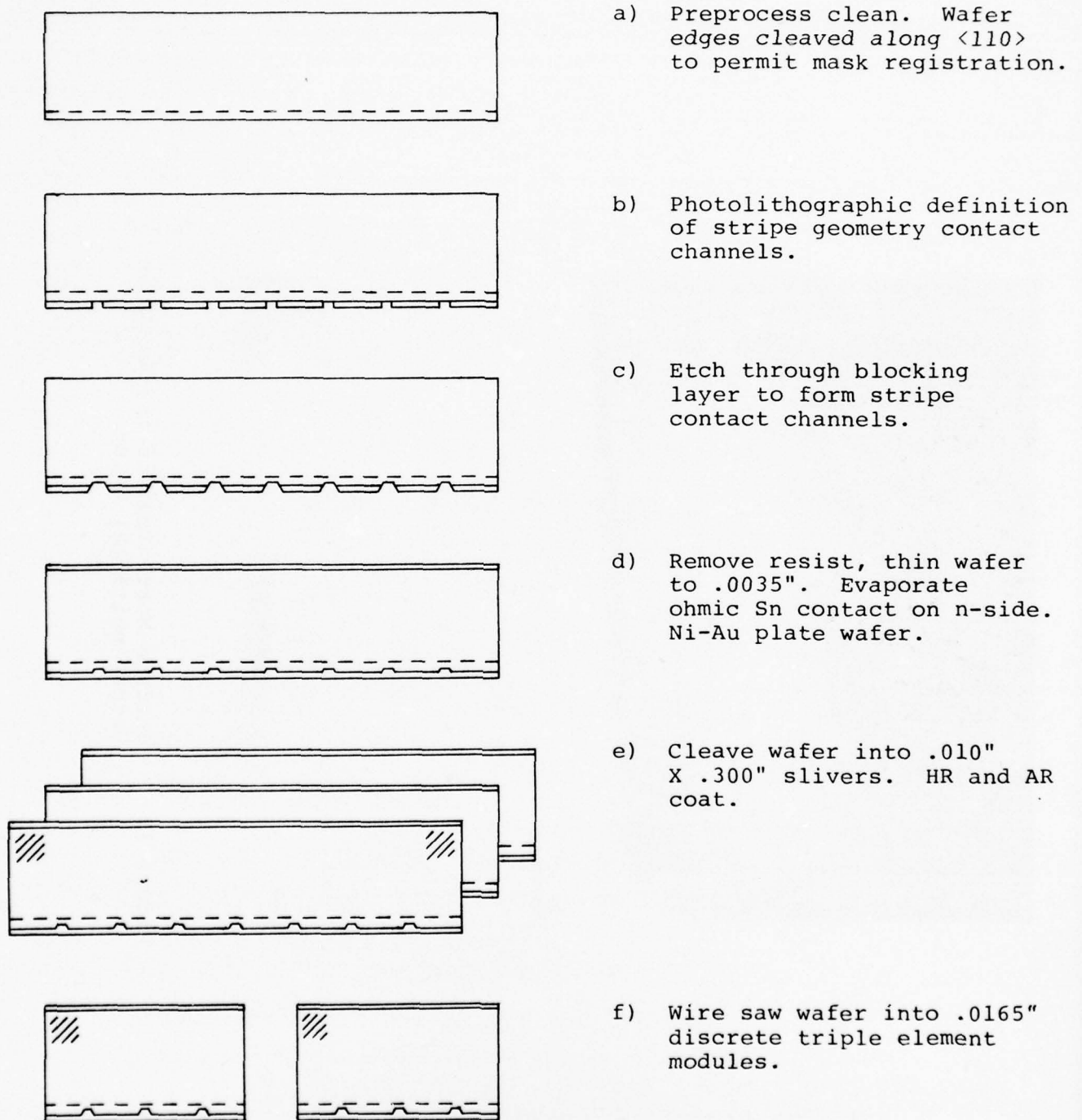


Figure 12 Surface Morphology of the As-Grown
Hetero-epitaxial Wafer.

Figure 13

Process flow diagram for the fabrication of monolithic stripe geometry injection laser arrays.



channels is accomplished by aligning the mask reference with the proper $\langle 110 \rangle$ direction as indicated schematically in Figure 13 (b).

Photolithographic definition is followed by a 3:1:1, Methanol:Phosphoric: Hydrogen Peroxide etch which removes the n-GaAs blocking layer forming an array of etched 20 μm wide contact channels in the p-GaAlAs contact cap. Parallel contact channels are spaced on .005" centers over the entire surface of the epitaxial wafer as shown in Figure 13 (c).

After removal of the masking resist, the epitaxial wafer is thinned to .0035" and Sn ohmic contacts are evaporated over the n-side of the thinned wafer, Figure 13 (d).

Ni-Au electroplated contacts are applied to both sides of the wafer forming ohmic contact to the exposed p-GaAlAs contact cap in the stripe channels.

Mirror facets are formed by cleaving the epitaxial wafer in the slivers approximately .010" by .300" as indicated schematically in Figure 13 (e).

Cleaving is accomplished with the aid of a diamond scribing apparatus shown in the photograph of Figure 14. The cavity length is accurately and reproducibly controlled by the micro-index control on the vacuum chuck of the scriber.

Reflective coating of the back facet of each sliver is accomplished by vacuum deposition of successive films of SiO (2000 \AA), Cr (50 \AA), Au (4000 \AA), Cr (100 \AA), and



Figure 14 Scribing Apparatus for Cleaving Epitaxial
Wafer into Slivers.

SiO (300\AA).

Finally, in Figure 13 (f), the individual slivers are cut on .025" centers with a ganged wire saw having a .0035" kerf.

Figure 15 shows an epitaxial wafer to which triple stripe geometry contacts have been applied. Figure 16 shows individual modules after they have been cleaved, coated, and cut to size ready for assembly onto the pill package.

3.2 Packaging Technology.

3.2.1 Package Design.

During the first quarter of the program, finalization of the package design and procurement of pill package blanks for fabrication of the first engineering samples was carried out. The pill package blank consists of a brass negative electrode, an Al_2O_3 ceramic spacer, and an OFHC copper positive electrode which serves as the primary heat sink for the monolithic triple stripe geometry injection laser diode module. These three major components are bonded together through the use of a high temperature alloying technique and are purchased from the supplier as a complete assembly. Engineering drawings for the piece parts are given in Figures 17 , 18 , and 19 . In addition to the package blank, the optical window along with its epoxy preform for attachment make up the remainder of the package parts. Parts drawings for these two components

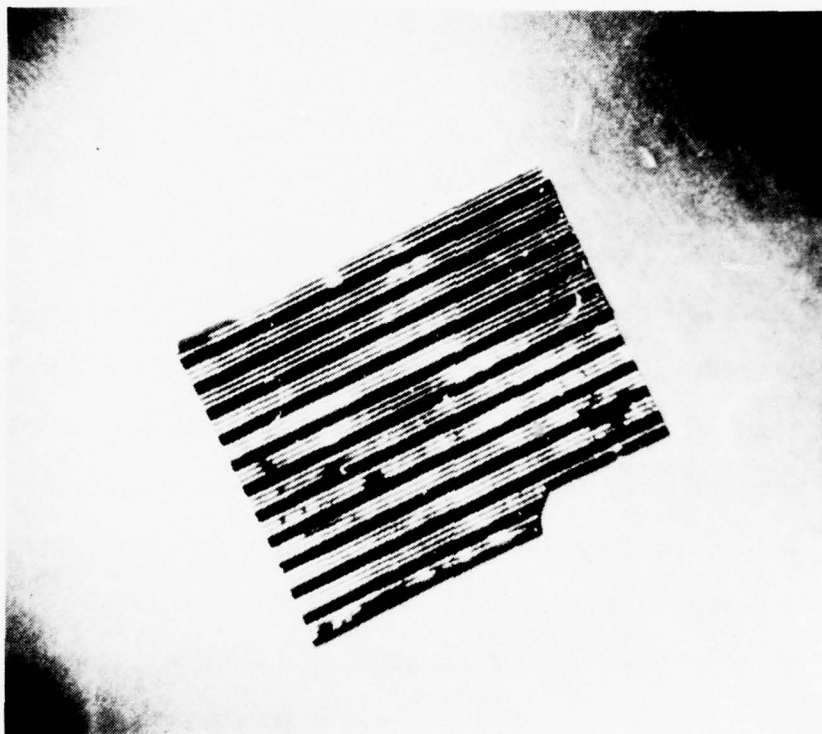


Figure 15 Photograph of Triple Stripe Geometry
Applied to Surface of an Epitaxial Wafer.

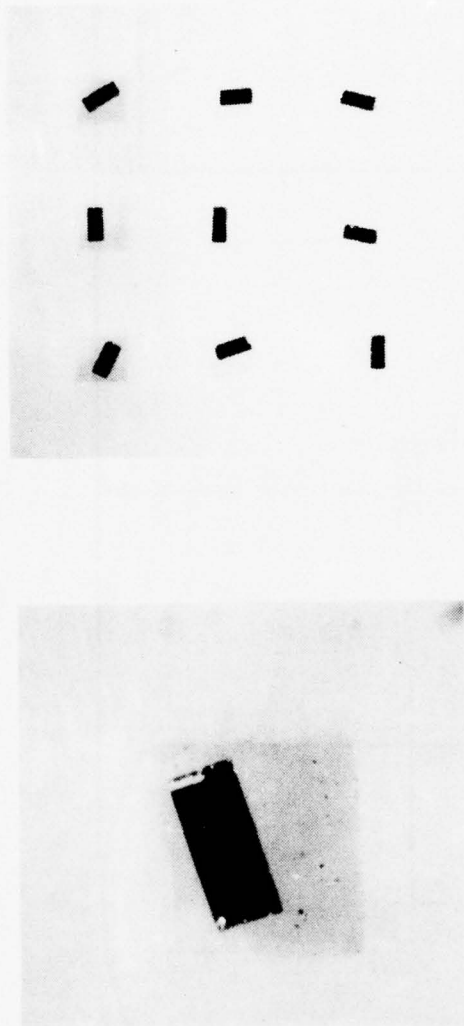
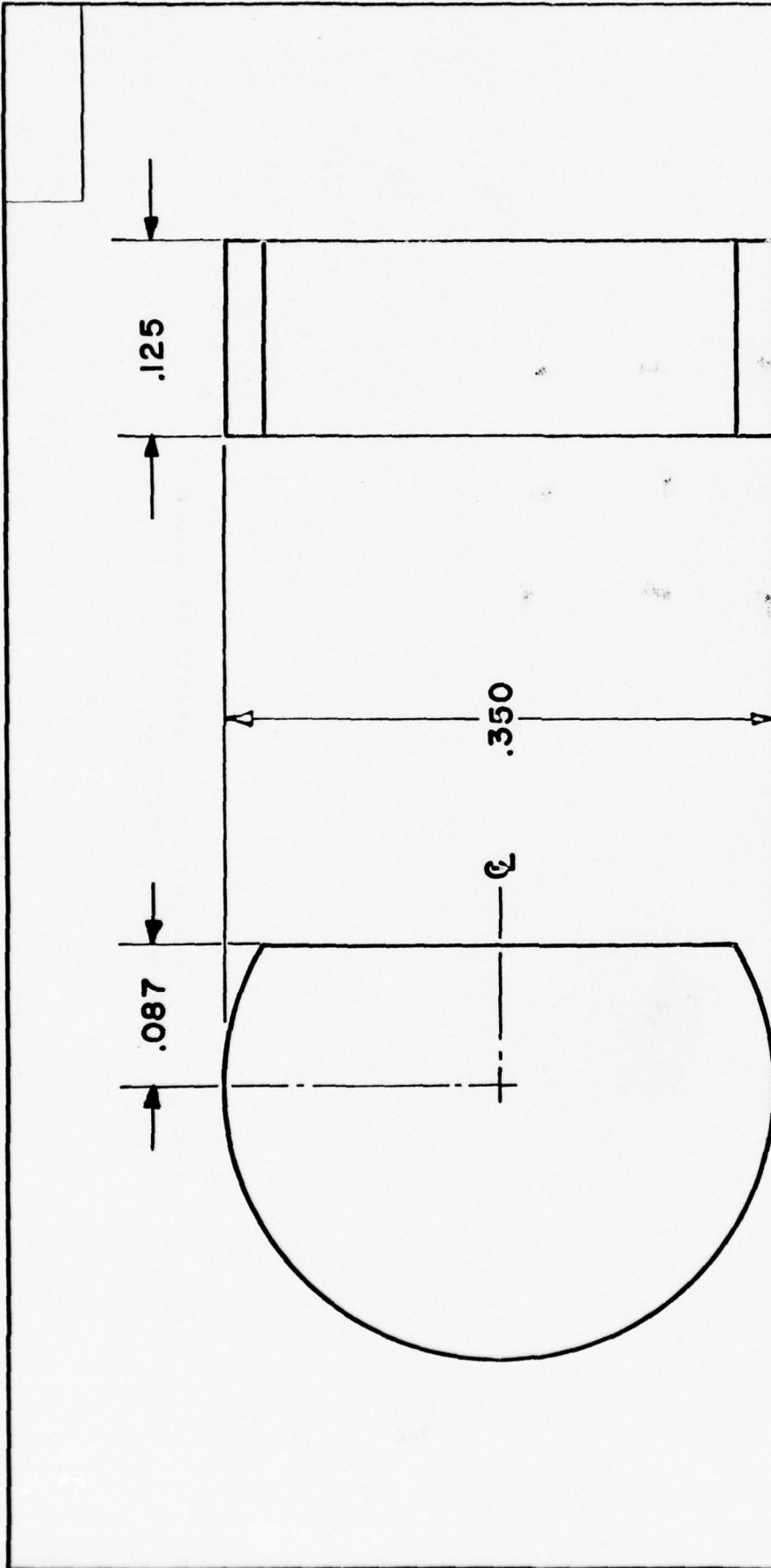


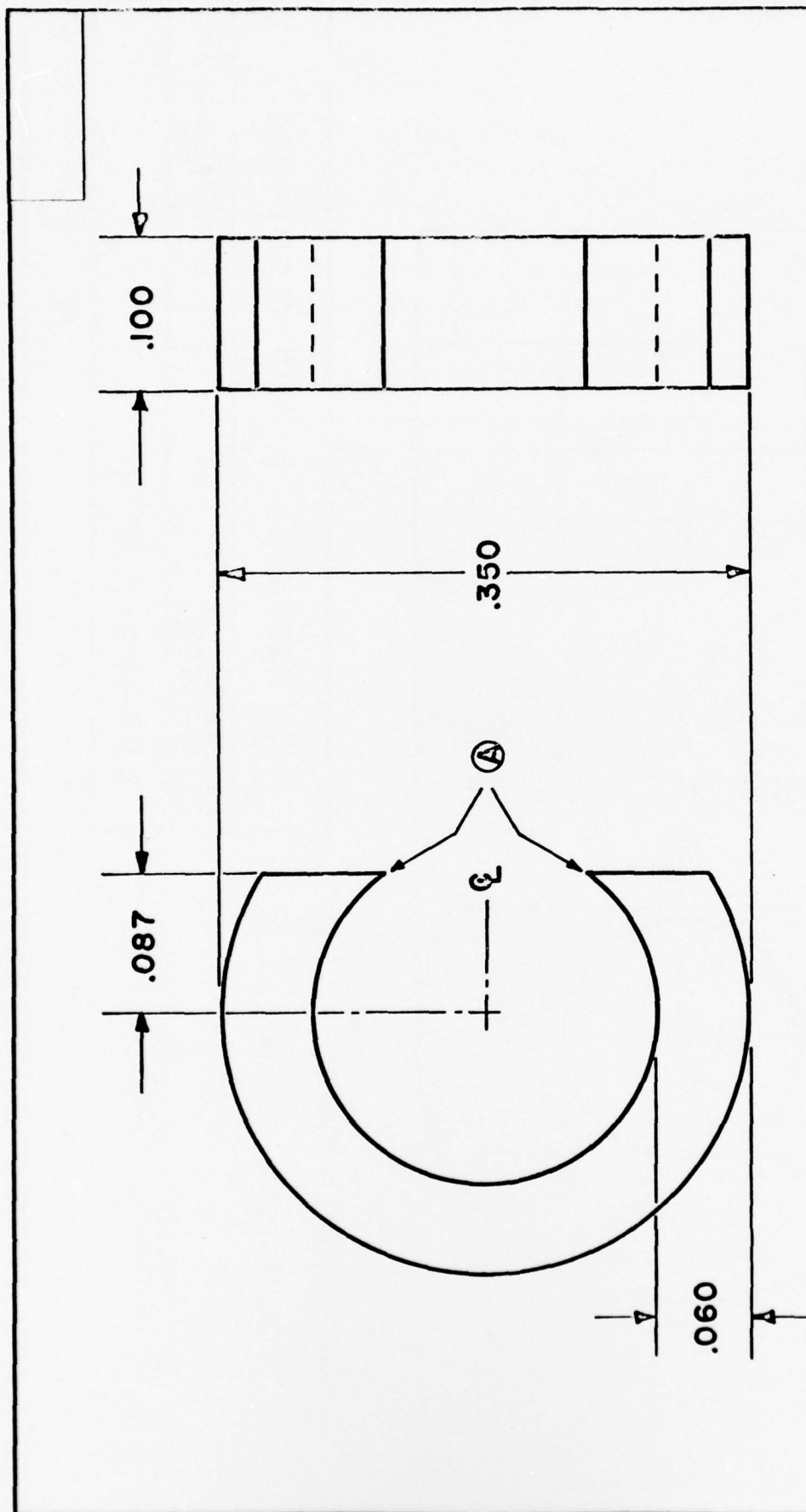
Figure 16 Photograph of Individual Triple
 Element Modules.



MATERIAL - OFHC COPPER
TOLERANCE: $\pm .002$

Figure 17 Pill Package - Mounting Base
 (Positive Electrode)

PILL PACKAGE		BOTTOM ELECTRODE	
SCALE: 10X	APPROVED BY	DRAWN BY	
DATE: 8-4-76		M.R.	
LDT-180A			
		DRAWING NUMBER	

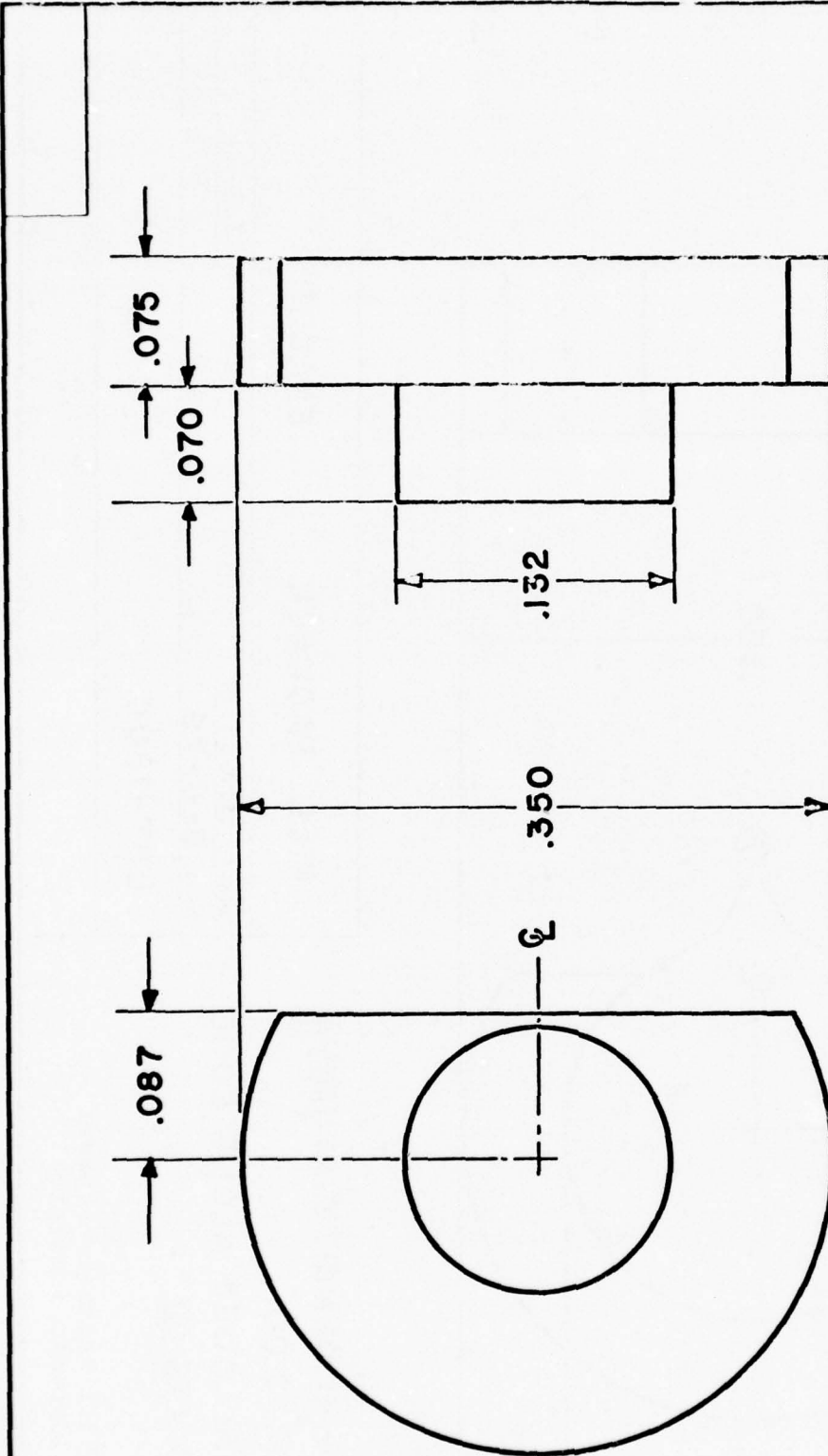


MATERIAL - HI DENSITY ALUMINA
TOLERANCE: $\pm .001$
.015 CHIP ALLOWED ALONG EDGE
AT POINTS A

PILL PACKAGE SPACER

SCALE: 10X	APPROVED BY	DRAWN BY
DATE: 8-4-76		M.R.
LDT-100C		
		DRAWING NUMBER

Figure 18 Pill Package - Spacer
 (Ceramic Insulator)

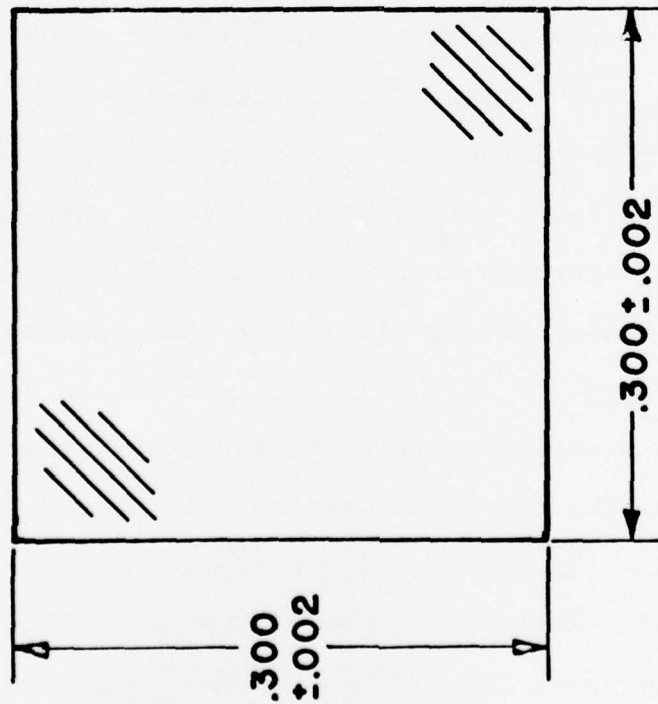


MATERIAL - BRASS
TOLERANCE: $\pm .002$

Figure 19 Pill Package - Cover Plate
 (Negative Electrode)

PILL PACKAGE		TOP ELECTRODE	
SCALE: 10X	APPROVED BY		DRAWN BY
DATE: 9-17-76			m.R.
LDT-180			
		DRAWING NUMBER	

are shown in Figures 20 and 21 and photographs of the window and preform are shown in Figure 22 (a) and (b). The epoxy utilized in this assembly is Ablestik type 539 and is supplied as a stamped preform. Type 539 consists of a non-frozen epoxy applied to both sides of a thin mylar film carrier. Preforms of this type are available in 0.0005" increments up to 0.003" thick. The epoxy is tack free prior to curing and can be stored at 25°C for an indefinite period of time. Curing is accomplished by heating to 110°C for two hours and results in an extremely uniform bond line with a shear strength of 3000 psi. Because extremely thin films of epoxy are applied to the mylar carrier, deformation of the preform during cure is minimized. This feature together with the inherent uniformity of the mylar film carrier makes this an ideal material for the attachment of the optical window to the laser diode pill package. In a parallel effort, the use of a similar mylar preform as an electrical insulator to be employed in place of the ceramic is currently under investigation. Several advantages to using epoxy preforms for this application have become evident to date. In order to obtain a perfectly flat mounting surface for the 0.004" thick optical window, the front face of the pill package blank must be lapped prior to use. The presence of the ceramic insulator introduces some degree of difficulty in this step owing to the difference in hardness between



NOTES:

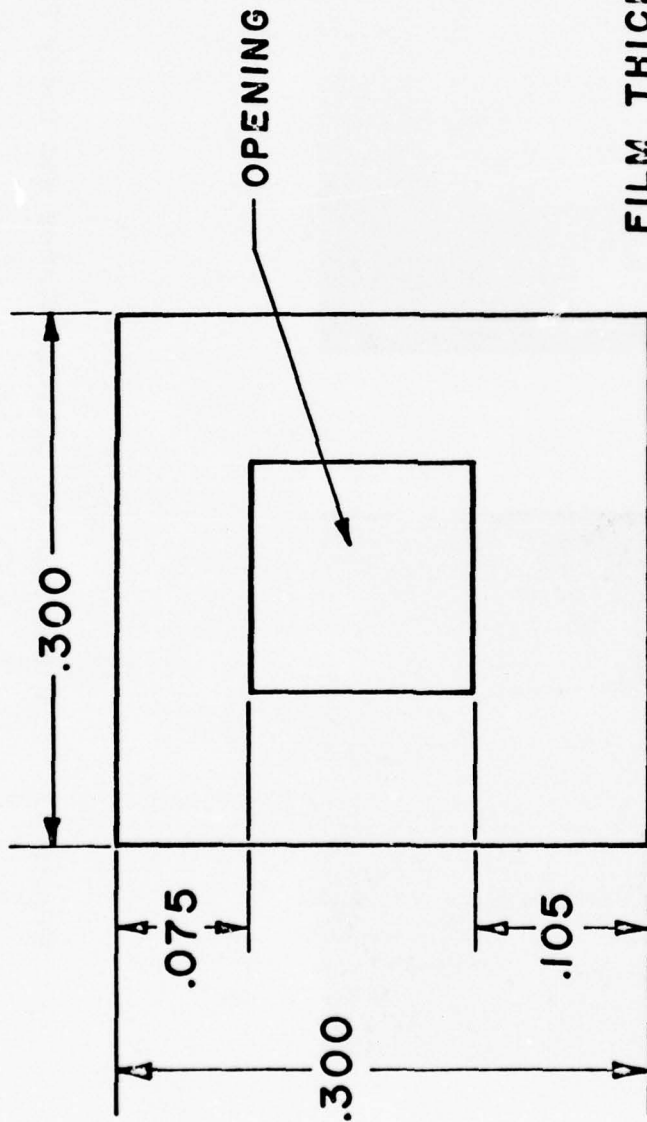
1. MATERIAL - QUARTZ - CLEAR,
FUZED
SAPPHIRE
2. COATING - AR COATED
FOR 320nm
BOTH SIDES.

THICKNESS - $.004 \pm .0005$

Figure 20 Pill Package -
Optical Window

WINDOW - PILL PACKAGE

SCALE: 10X	APPROVED BY	DRAWN BY
DATE: 9-16-76		M.R.
LDT-179		
		DRAWING NUMBER



FILM THICKNESS
.0015

MATERIAL - ABLESTIK
ABLEFILM 539 - TYPE I

PILL PACKAGE - EPOXY PREFORM

SCALE: 10X	APPROVED BY	DRAWN BY
DATE: 9-1-76		M. J.
LDT-179		
		DRAWING NUMBER

Figure 21 Pill Package - Epoxy Preform

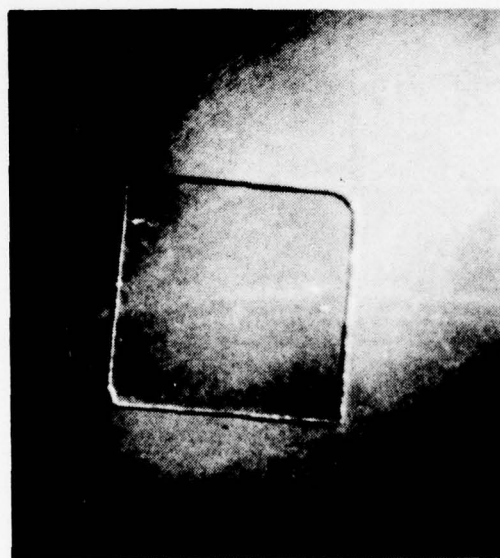
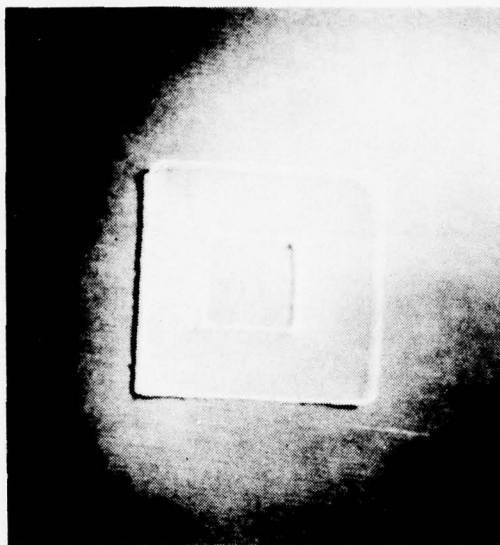
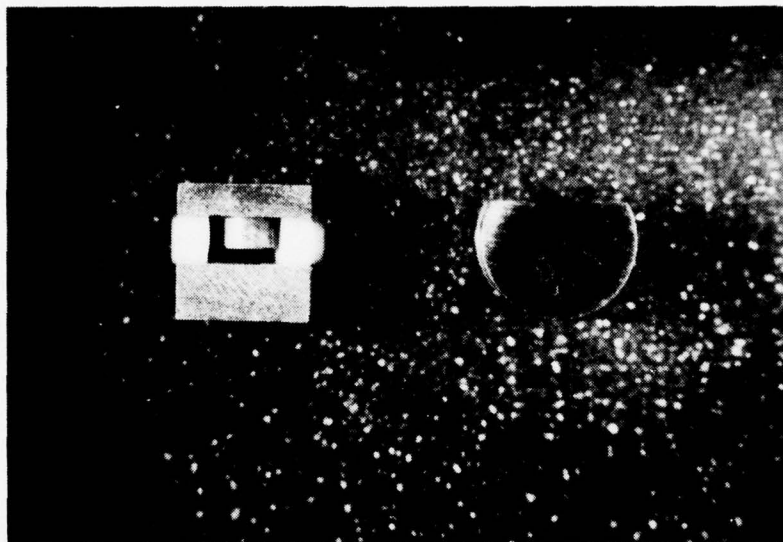


Figure 22 Photograph of Optical Window and Epoxy Preform.

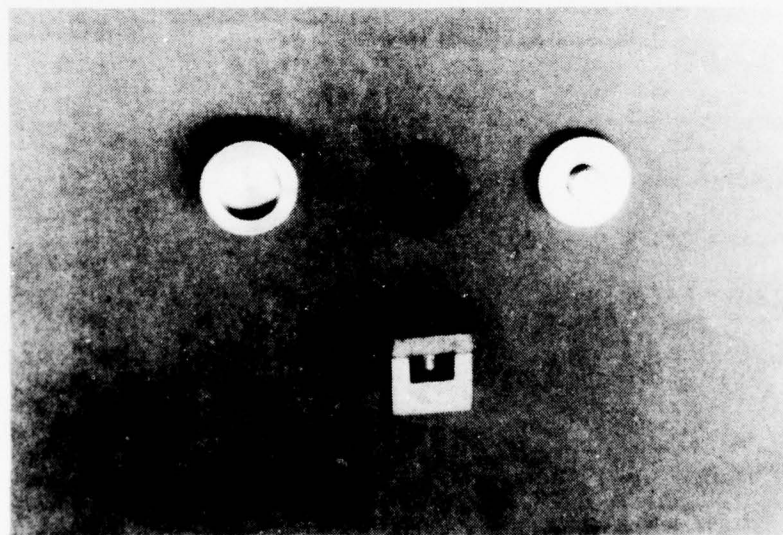
Al_2O_3 and copper. Although perfectly flat mounting faces can be obtained, the lapping must be done carefully to prevent rounding. When the blank is designed for use with an epoxy-mylar insulator, the lapping accomplished with much less difficulty and with a minimum of material removal. In addition, the copper-mylar blank is about one third as costly as its copper ceramic counterpart. Photographs of both types of pill package blanks are shown in Figure 23 (a) and (b). Experiments to determine the impact on environmental and electro-optical characteristics due to the incorporation of the mylar insulator are currently underway.

3.2.2 Assembly Technique.

A blow up of the injection laser diode pill package assembly is illustrated in Figure 24. The device is assembled in the following sequence of procedures. The window mounting face of the pill package blank is first lapped flat using the lapping machine shown in Figure 25. Blanks are mounted in a special fixture to facilitate batch processing of the parts. The pill package blanks are then individually inspected and are deburred prior to electroless plating with nickel and gold. Next, the fly ribbon is welded to the negative electrode of the package. A photograph of the welding apparatus is shown in the photograph of Figure 26. At this point, pre-tested laser diode modules are mounted on the pill package and the fly ribbon is attached to the n-side



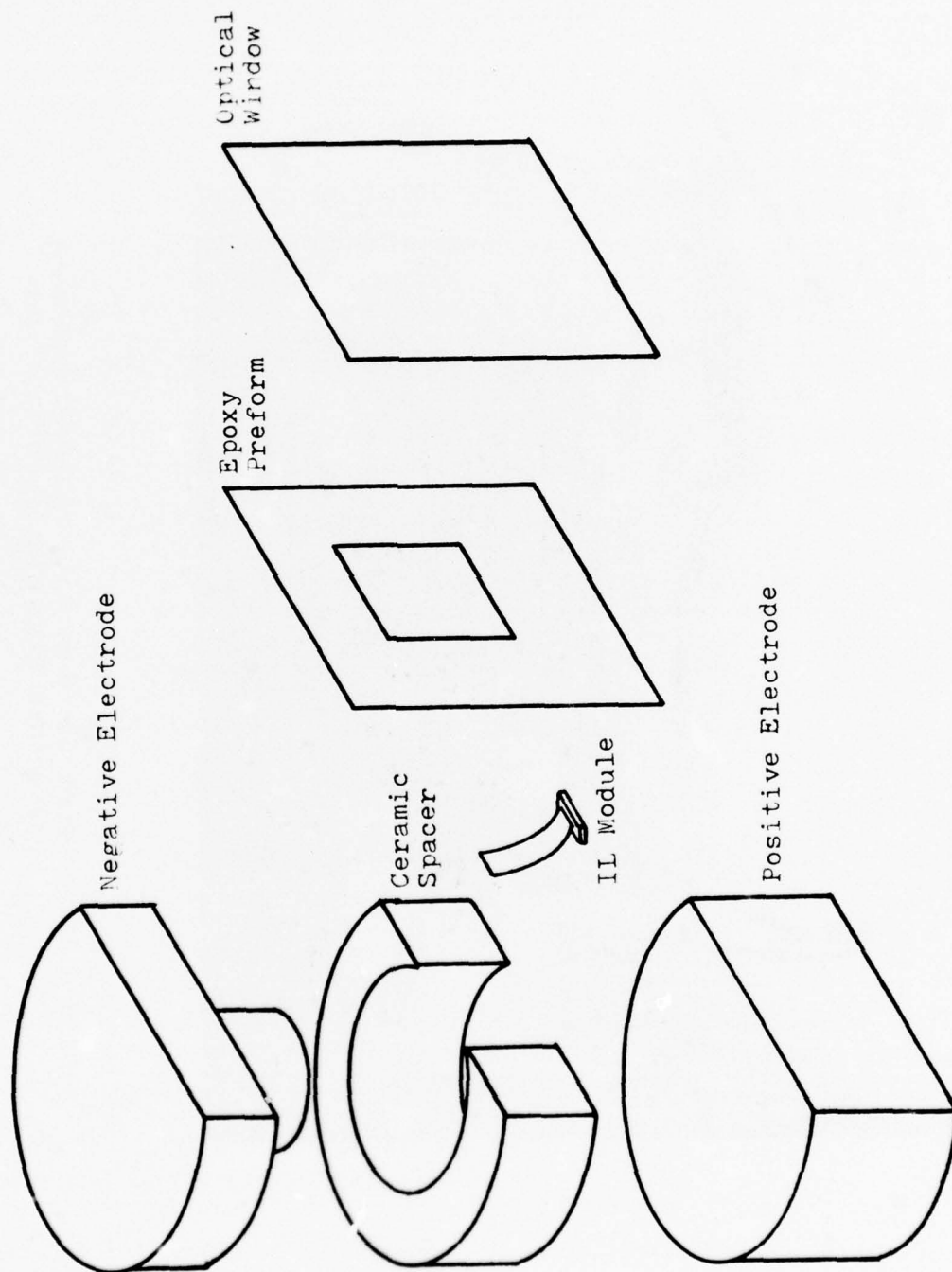
a. Cu-Ceramic Blank. (2.5x)



b. Cu-Mylar Blank. (1.5x)

Figure 23 Pill Package Blanks

Figure 24 Blow Up of Pill Package Injection
Laser Diode Assembly.



(Refer to Figure 3 for Outline Dimensions)

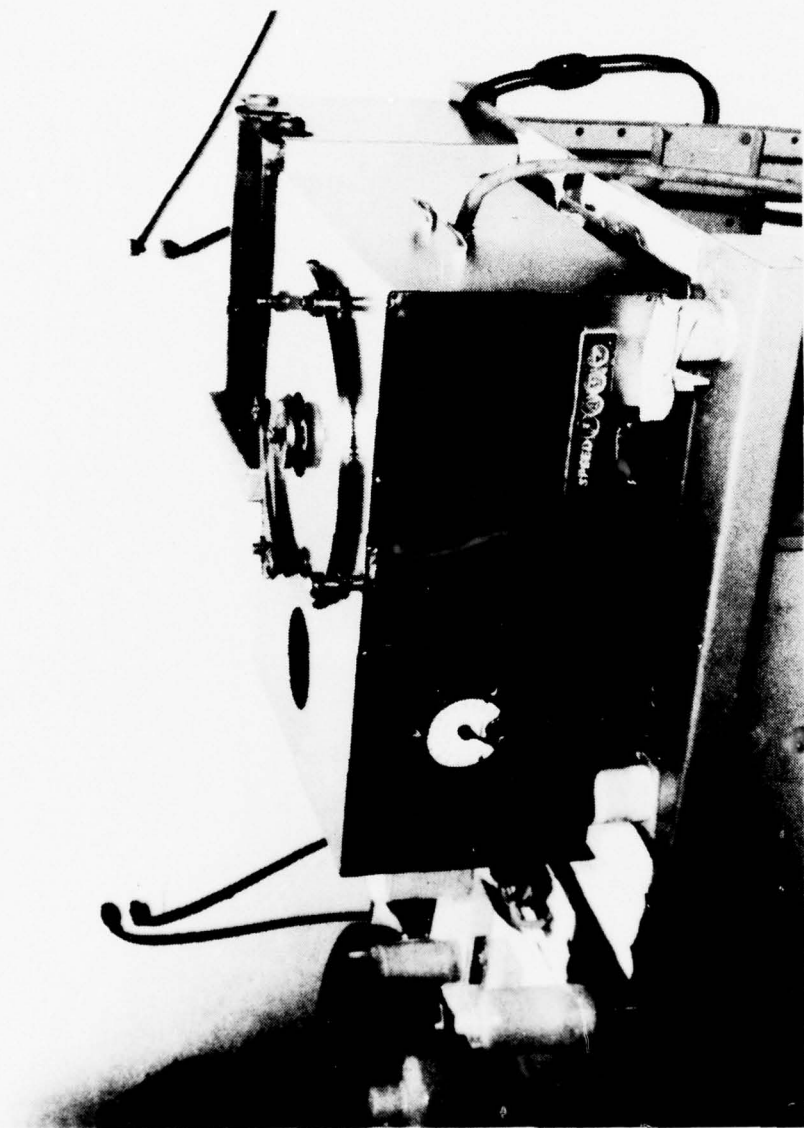


Figure 25 Photograph of Lapping Apparatus used
to Obtain Flat Window Mating Face.

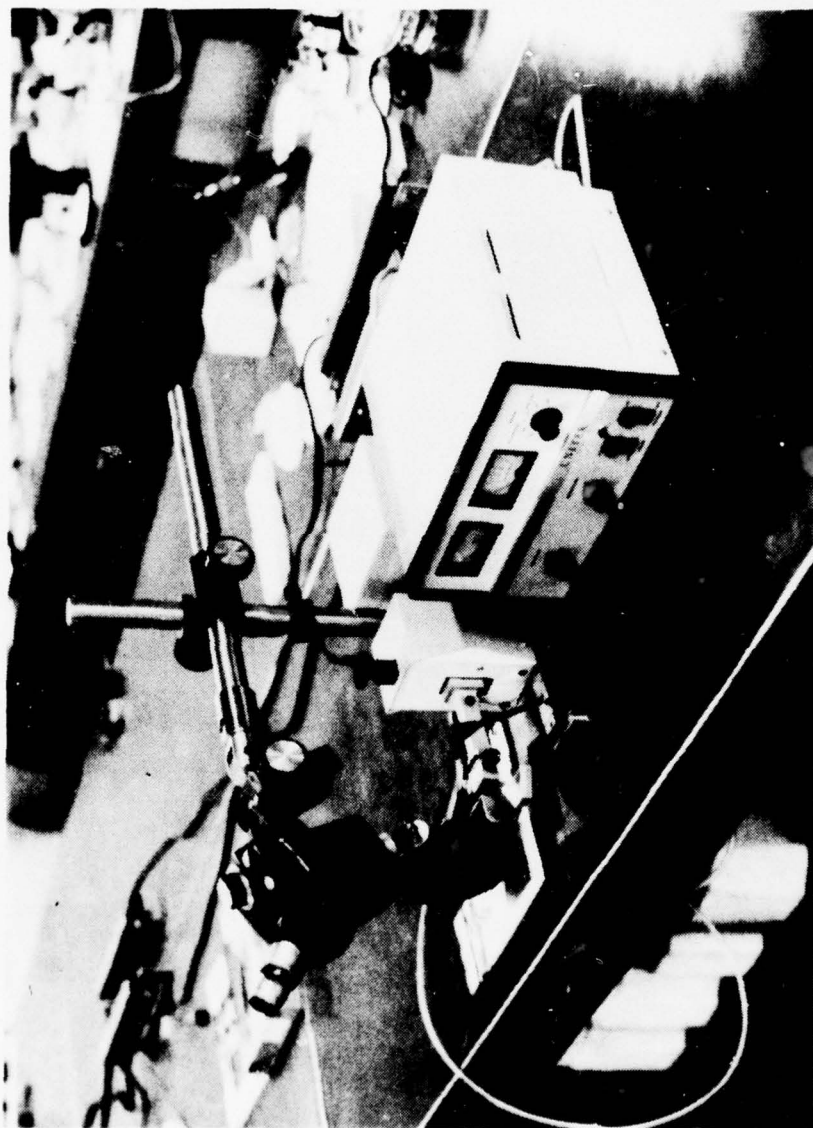


Figure 26 Welding Apparatus for Fly Ribbon Attachment.

of the module with indium. After undergoing an electro-optical parameter screen, anti-reflective coatings will be applied to the passed diode assemblies. To date, AR coatings have not been incorporated on prototype diodes because construction of the electron beam deposition system is not scheduled for completion until the end of the next quarter. A photograph of the multipot E-gun source is shown in Figure 27.. A critical step in the fabrication of the injection laser diode assembly is the attachment of the optical window to the package. A special assembly station, shown in Figure 28 , has been designed to permit the attachment of the optical window in a dust-free, dry nitrogen ambient environment. The entire process including epoxy cure must take place in an inert gas in order to avoid the potentially detrimental effects of both moisture and oxygen contamination of the monolithic triple stripe geometry injection laser diode. A photograph of the completed assembly is shown in Figure 29. .

3.3. Device Evaluation and Testing.

3.3.1 Test Equipment.

A 10 MHz pulser capable of delivering drive currents up to 3.0 amperes at a duty factor of 10% forms the basis for all of the electro-optical measurements to be carried out during the course of this program. The first 25 positions of the burn-in and life test rack

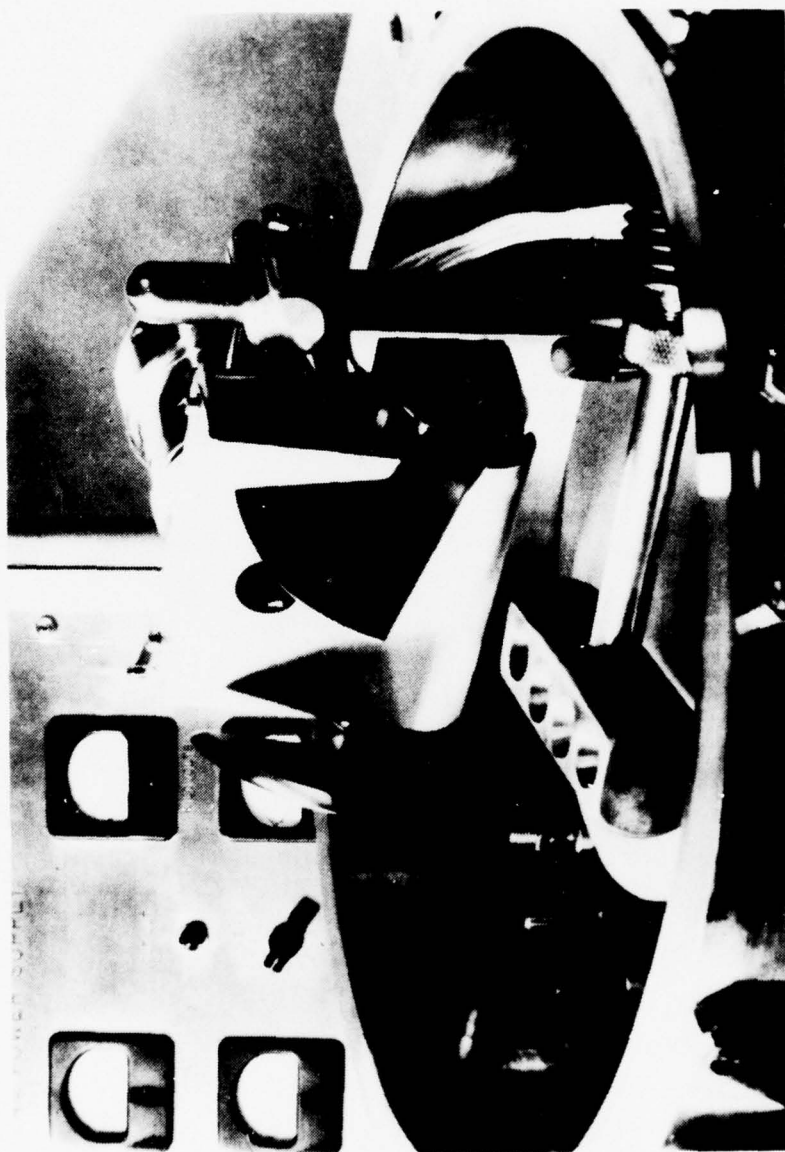


Figure 27 Photograph of Multi-pot E-gun Deposition
Source for the Application of Optical Coatings.



Figure 28 Assembly Station for Attachment of the
Optical Window.

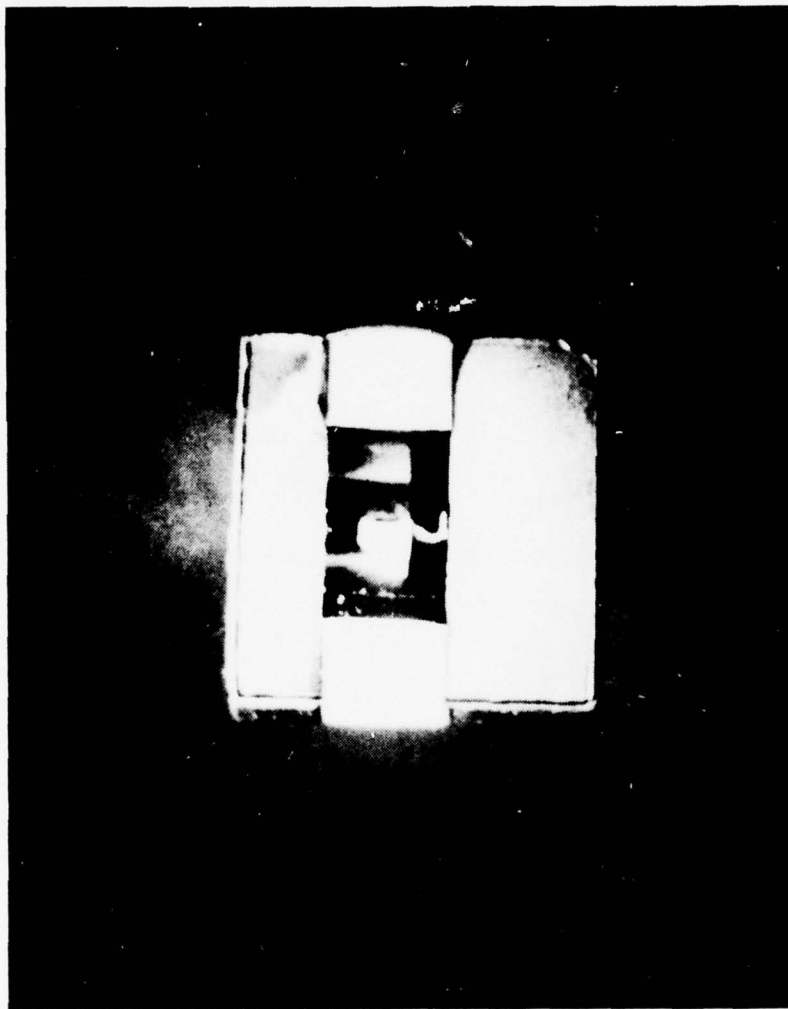


Figure 29 Photograph of Completed Injection
Laser Assembly. (Refer to Figure 24
for Further Detail.)

are currently under construction and are scheduled for completion during the second quarter of the program. The circuit schematic for this driver is shown in Figure 30. A prototype circuit board has been evaluated for stability and has exhibited highly satisfactory performance over a 500 hour period.

3.3.2 Prototype Laser Performance.

Initial evaluations of double heterojunction material were carried out on structures having cavity dimensions of greater than $1.0\mu\text{m}$. Figure 31 shows a photograph of an etched cross section of DH-A-97.

Modules fabricated from this epitaxial wafer consisted of triads of $.001"$ contact stripes. A portion of one of these etched channels can be seen clearly on the p-side (top edge) of the epitaxial wafer. The primary reason for choosing a wide cavity structure for the initial prototype evaluation was to determine the baseline or 'worst case' performance characteristics of the device. In addition, by comparing broad area to stripe geometry lasing characteristics for fixed cavity lengths, and accurate estimate of degree of current spreading can be made for a given epitaxial configuration. In the case of DH-A-97, which had a $1.4\mu\text{m}$ cavity, J_{th} for stripe geometry laser diodes was $14\text{KA}/\text{cm}^2$ i.e. $J_{\text{th}}/d = 10\text{KA}/\text{cm}^2/\mu\text{m}$. J_{th}/d for broad area contacts was $6.5\text{KA}/\text{cm}^2/\mu\text{m}$ indicating considerable current spreading in the wide cavity structure. Modules fabricated from DH-A-97, exhibited an average threshold of 3.2 amperes and a dif-

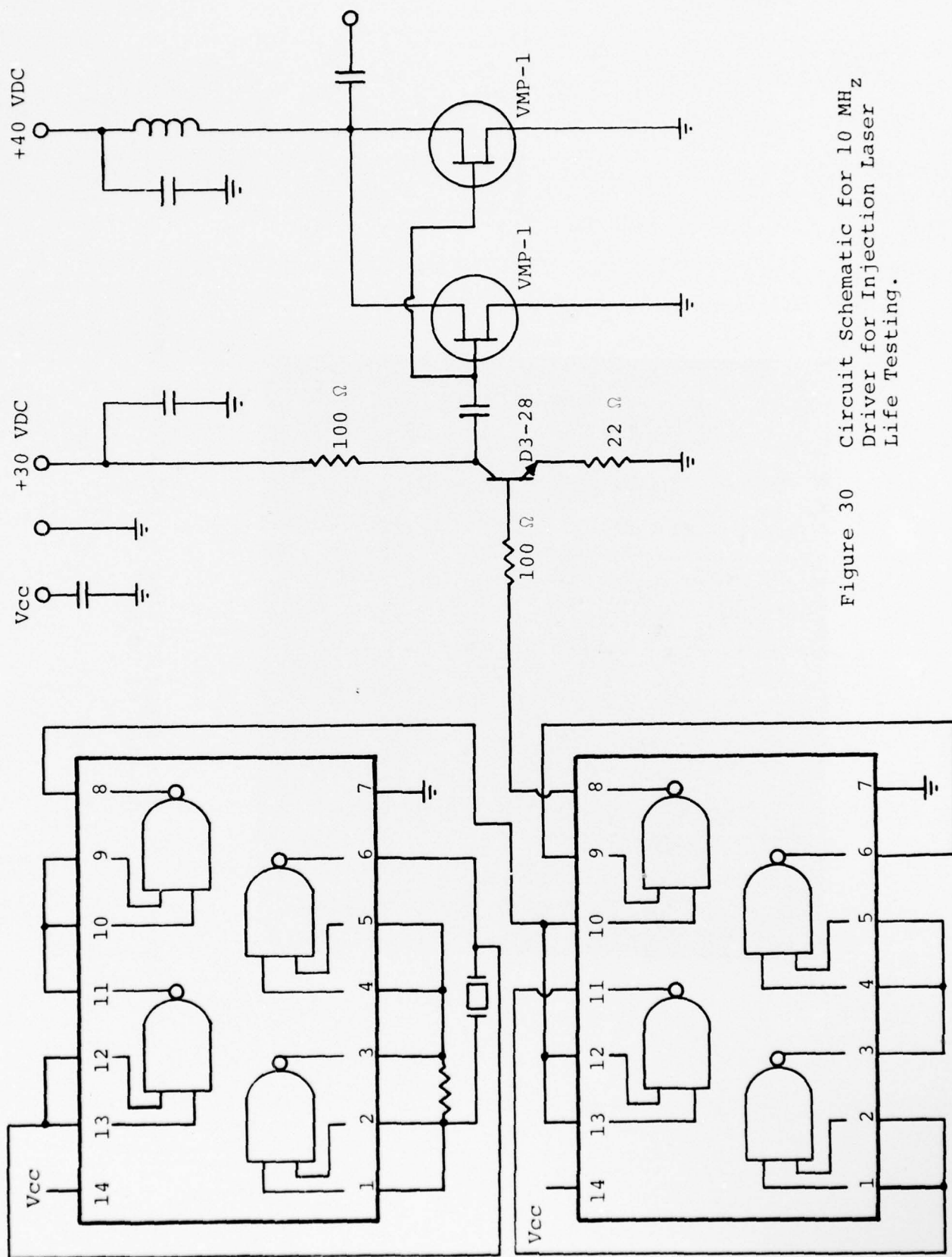


Figure 30
Circuit Schematic for 10 MHz
Driver for Injection Laser
Life Testing.

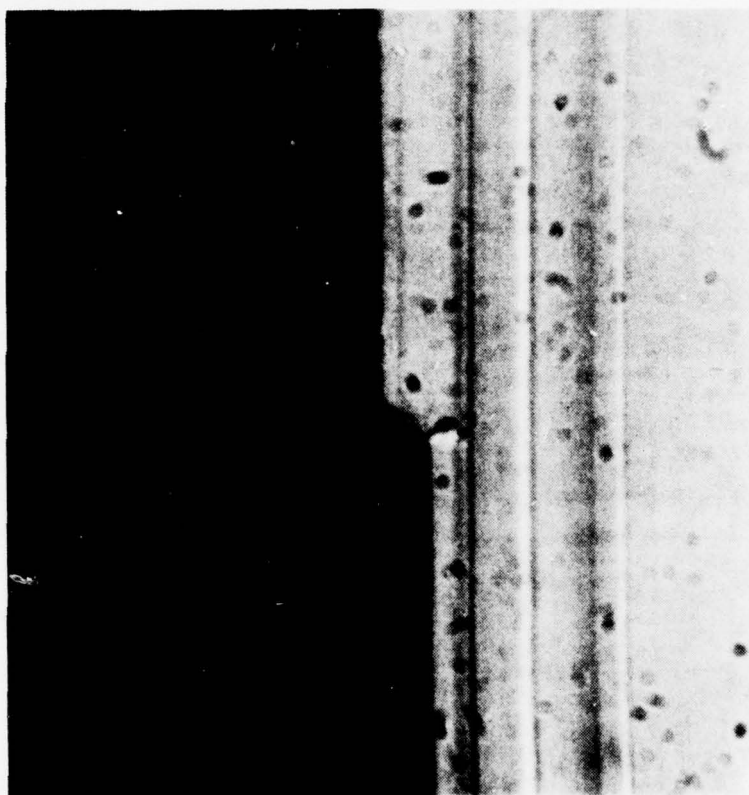


Figure 31 Photograph of Cleaved and Etched Cross
Section of DH-A-97.

ferential quantum efficiency of 30% with no optical coatings applied to the facets of the diode.

Based on this data, structures having a cavity width, d , equal to $0.4\text{ }\mu\text{m}$ require a stripe width of approximately $15\text{ }\mu\text{m}$ in order to maintain an optical source size less than $25\text{ }\mu\text{m}$ wide. The maximum threshold current for devices with a $0.4\text{ }\mu\text{m}$ cavity will be about 350 ma for each element of the triad. In reality, since the amount of current spreading decreases with decreasing cavity width, threshold current is expected to be somewhat lower than this figure. In addition, the output power at 2 amperes drive should exceed 200 mW based on the 30% efficiency measurement.

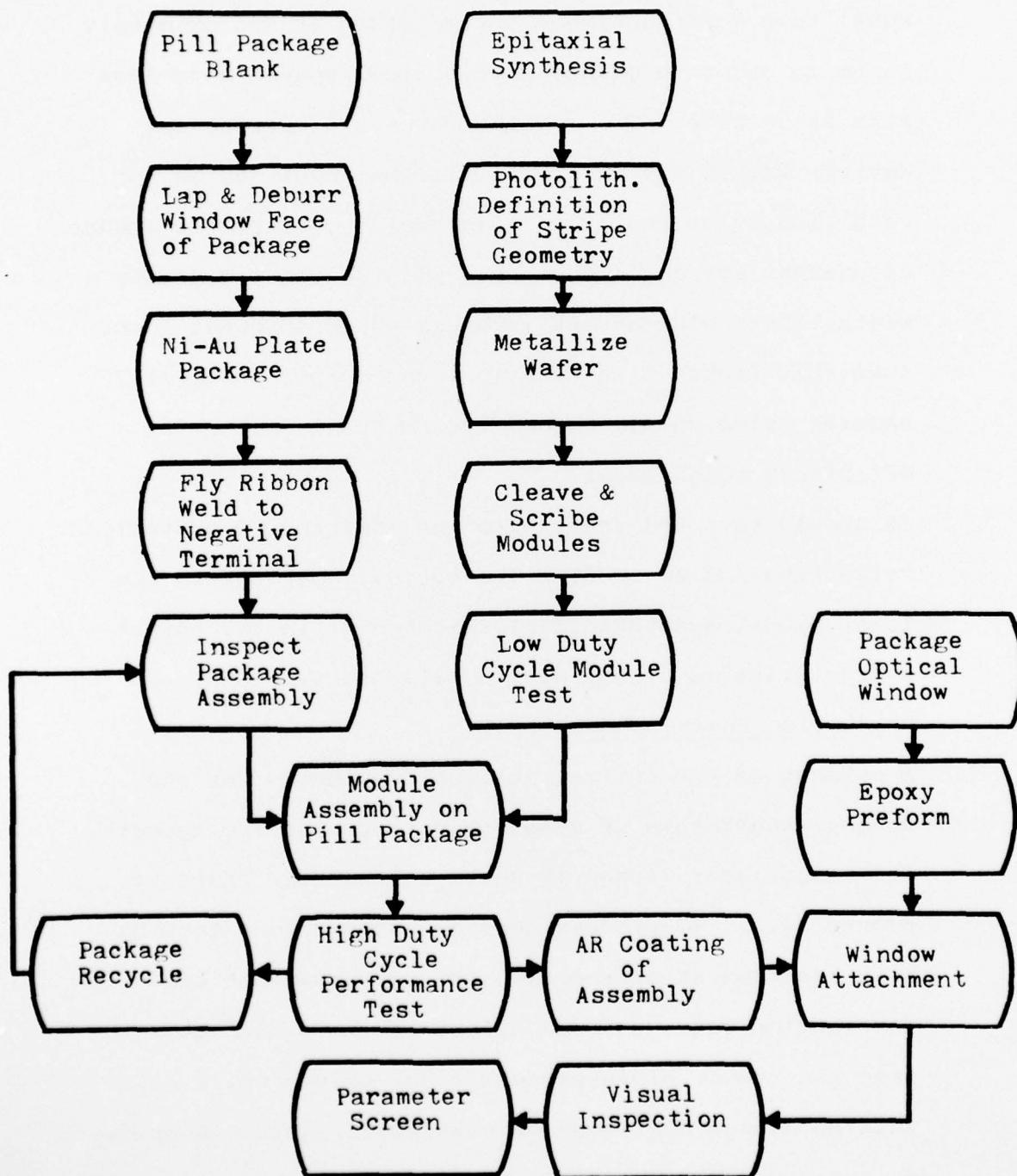
It should be noted that, with the addition of suitable reflective and antireflective optical coatings to the laser diode, a substantial improvement in the output characteristics of the device will occur.

3.4 Production Engineering.

A summary of the entire fabrication process for the volume manufacture of monolithic triple stripe geometry injection laser diodes is shown in the flow chart of Figure 32. . In-process test and inspection steps have been inserted at appropriate points throughout the fabrication sequence. An effort has been made to minimize the number of in-process check points while maintaining a high degree of process efficiency. An estimate to minimum man-hour requirements for the fabrication of

Figure 32

Flow chart of Manufacturing process for triple Stripe Geometry Injection Laser Diode.



the injection laser at a rate of 100 units per day is included in Table 3 . In some cases the minimum throughput at a given operation exceeds the daily requirement of the program. In these cases, the minimum man-hour requirement, is based on the amount of time required to complete a given operation even if that operation yields more than the required number of devices. For example, if optical coatings are applied to a number of slivers, the time required may be 2.4 hours minimum regardless of whether 100 modules or 500 modules can be coated in the same operation.

SECTION IV

SUMMARY AND CONCLUSIONS

The first quarter of the program has witnessed the procurement of all essential components for the fabrication of the engineering prototypes. Preliminary evaluations carried out for the purpose of determining optimum material design parameters have been completed. The results of these studies indicate that contact stripe widths of 15 μm may be required in order that the threshold current be kept below 1.0 ampere for the triad and the optical source size be kept below 25 μm for each element of the triad.

Potential problem areas involving window attachment have been identified and solutions proposed. A modified pill package, which employs a mylar insulator in place of the ceramic spacer, is currently under consideration as

Table 3

Minimum Man Hour Requirements for Fabrication of
Monolithic Stripe Geometry Injection Laser Diodes.

<u>Manufacturing Sequence</u>	<u>Man hour Requirement</u>
1. Epitaxial Synthesis	4.0
2. Photolithography	1.4
3. Metalization	1.1
4. Cleaving	1.0
5. HR Coating	2.4
6. Cutting	4.2
7. Module Pretest	1.5
8. Package Preparation	5.0
9. Welding	0.6
10. Diode Mounting	12.0
11. Device Pretest	1.5
12. AR Coating	4.8
13. Window Attachment	6.0
14. Inspection -	1.5

* Figures are yield adjusted for a rate of
100 units per day.

one possible solution to the problem of obtaining a perfectly flat window mating face.

Plans for the next quarter include the fabrication, testing, and delivery of the first set of engineering samples. In addition, the installation of the electron beam gun required for the deposition of antireflective coatings is scheduled for completion. The first 50 burn-in and life test positions will also be completed during the second quarter of the program.

TABLE 4

Engineering Man-Hour Totals for the First Quarter
of the Program.

R. B. Gill	President	138 Hrs.
T. E. Stockton	Operations Manager	376 Hrs.
R. E. Albano	Technical Staff Member	160 Hrs.
A. Gennaro	Technical Staff Member	154 Hrs.
S. Klunk	Technical Staff Member	86 Hrs.

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